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Bulletin No. 285 Series A, Economic Geology, 73

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

CONTRIBUTIONS

TO

ECONOMIC GEOLOGY

1905

S. F. EMMONS
E. C. ECKEL
Geologists in Charge

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CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1905.

S. F. EMMONS, E. C. ECKEL, *Geologists in Charge.*

INTRODUCTION.

By C. W. HAYES, *Geologist in Charge of Geology.*

This bulletin is the fourth of a series, including Bulletins Nos. 213, 225, and 260, Contributions to Economic Geology for 1902, 1903, and 1904, respectively. These bulletins are prepared primarily with a view to securing prompt publication of the economic results of investigations made by the United States Geological Survey. They are designed to meet the wants of the busy man, and are so condensed that he will be able to obtain results and conclusions with a minimum expenditure of time and energy. They also afford a better idea of the work which the Survey as an organization is carrying on for the direct advancement of mining interests throughout the country than can readily be obtained from the more voluminous reports.

In the first two bulletins of this series were included numerous papers relating to the economic geology of Alaska. In view of the rapid increase of economic work both in Alaska and in the States and the organization of a division of Alaskan mineral resources, distinct from the division of geology, it was last year considered advisable to exclude all papers relating to Alaska. These were brought together in a separate volume entitled "Report of Progress of Investigations of Mineral Resources of Alaska in 1904," Bulletin No. 259. A similar segregation of papers relating to Alaska has been made this year.

In the preparation of the present volume promptness of publication has been made secondary only to the economic utility of the material presented. The papers included are such only as have a direct economic bearing, all questions of purely scientific interest being excluded.

The papers are of two classes: (1) Preliminary discussions of the results of extended economic investigations, which will later be published by the Survey in more detailed form; (2) comparatively detailed descriptions of occurrences of economic interest, noted by geologists of the Survey in the course of their field work, but not of sufficient importance to necessitate a later and more extended description. A third class of papers was included in the bulletin for 1902—namely, abstracts of certain economic papers which had appeared in Survey publications during the year, chiefly such as gave a general account of the distribution and mode of occurrence of particular mineral deposits throughout the United States. Most of the publications on economic geology which have appeared during the past year were abstracted for advance publication in Bulletin 260, and it has therefore been unnecessary to abstract them in this volume.

The papers have been grouped according to the subjects treated. At the end of each section is given a list of previous publications on that subject by this Survey. These lists will be serviceable to those who wish to ascertain what has been accomplished by the Survey in the investigation of any particular group of mineral products. They are generally confined to Survey publications, though a few titles of important papers published elsewhere by members of the Survey are included.

The results of the Survey work in economic geology have been published in a number of different forms, which are here briefly described:

1. *Papers and reports accompanying the Annual Report of the Director, United States Geological Survey.*—Prior to 1902 many economic reports were published in the royal octavo cloth-bound volumes which accompanied the Annual Report of the Director. This form of publication for scientific papers has been discontinued and a new series, termed Professional Papers, has been substituted.

2. *Bulletins of the United States Geological Survey.*—The bulletins of the Survey comprises a series of paper-covered octavo volumes, each containing usually a single report or paper. These bulletins, formerly sold at normal prices, are now distributed free of charge to those interested in the special subject discussed in any particular bulletin. This form of publication facilitates promptness of issue for economic results, and most economic reports are therefore published as bulletins. Their small size, however, precludes the use of large maps or plates, and reports containing large illustrations are therefore issued in the series of Professional Papers.

3. *Professional Papers of the United States Geological Survey.*—This series, paper covered, but quarto in size, is intended to include such papers as contain maps or other illustrations requiring the use of a large page. The publication of the series was commenced in 1902, and the papers are distributed in the same manner as are the bulletins.

4. *Monographs of the United States Geological Survey.*—This series consists of cloth-bound quarto volumes, and is designed to include exhaustive treatises on economic or other geologic subjects. Volumes of this series are sold at cost of publication.

5. *Geologic folios of the United States Geological Survey.*—Under the plan adopted for the preparation of a geologic map of the United States the entire area is divided into small quadrangles, bounded by certain meridians and parallels, and these quadrangles, which number several thousand, are separately surveyed and mapped. The unit of survey is also the unit of publication, and the maps and discriptions of each quadrangle are issued in the form of a folio. When all the folios are completed they will constitute a Geologic Atlas of the United States.

A folio is designated by the name of the principal town or of a prominent natural feature within the quadrangle. It contains topographic, geologic, economic, and structural maps of the quadrangle, and occasionally other illustrations, together with a general description.

Under the law copies of each folio are sent to certain public libraries and educational institutions. The remainder are sold at 25 cents each, except such as contain an unusual amount of matter, which are priced accordingly.

Circulars containing lists of these folios, showing the locations of the quadrangular areas they describe, their prices, etc., are issued from time to time, and may be obtained on application to the Director of the United States Geological Survey. The following list shows the folios issued to date and the economic products discussed in the text of each, the products of greatest importance being printed in italic.

List of geologic folios, showing mineral resources described.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
1	Livingston	Mont	3,354	Iddings, J. P.; Weed, W. H.	Gold, copper, clays, lime stone, *coal*.
2	Ringgold	Ga.-Tenn	980	Hayes, C. W	*Coal, iron*, manganese, lime, clays, stone, road metal.
3	Placerville	Cal	932	Lindgren, W.; Turner, H. W.	*Gold*, copper, quicksilver chromite, stone.
4	Kingston	Tenn	969	Hayes, C. W	*Coal, iron*, lime, stone, road metal, clay.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
5	Sacramento	Cal	932	Lindgren, W	*Gold*, copper, chromite, iron, coal, stone, lime, clay.
6	Chattanooga	Tenn	975	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
7	Pikes Peak	Colo	932	Cross, W	*Gold*.
8	Sewanee	Tenn	975	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
9	Anthracite-Crested Butte.	Colo	465	Emmons, S. F.; Cross, W.; Eldridge, G. H.	*Coal*, *silver*, gold, stone, lime, clay.
10	Harpers Ferry	Va.-W. Va.-Md.	925	Keith, A	*Iron*, *ocher*, copper, stone, road metal, lime, cement rock.
11	Jackson	Cal	938	Turner, H. W	*Gold*, *copper*, chromite, iron, manganese, ocher, coal, stone, lime, clay.
12	Estillville	Va.-Ky.-Tenn.	957	Campbell, M. R	*Coal*, iron, marble, limestone.
13	Fredericksburg	Md.-Va	938	Darton, N. H	*Greensand marl*, stone, fuller's earth, clays, sand, gravel, *underground water*.
14	Staunton	Va.-W. Va	938	.....do	Iron, marble, lime, clay, coal.
15	Lassen Peak	Cal	3,634	Diller, J. S	Gold, infusorial earth lime, stone, coal.
16	Knoxville	Tenn.-N. C	969	Keith, A	*Marble*, slate, stone, gold, lime, cement, clay, water-power.
17	Marysville	Cal	925	Lindgren, W.; Turner, H. W.	*Gold*, coal, gas, clay, lime, stone, water.
18	Smartsville	.....do	925	.....do	*Gold*, copper, quicksilver iron, lime, brick, clay stone.
19	Stevenson	Ga.-Ala.-Tenn.	980	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
20	Cleveland	Tenn	975	.....do	*Iron*, lead, lime, stone, clay
21	Pikeville	.....do	969	.....do	*Coal*, iron, stone, clay.
22	McMinnville	.....do	969	.....do	*Coal*, iron, stone, clay.
23	Nomini	Md.-Va	938	Darton, N. H	*Greensand marl*, fuller's earth, clay, stone, sand, gravel, *underground water*.
24	Three Forks	Mont	3,354	Peale, A. C	*Gold*, silver, copper, iron, coal, lime, clay, pumice, *mineral water*.
25	Loudon	Tenn	969	Keith, A	*Coal*, marble, lime, stone, clay, iron, slate.
26	Pocahontas	Va.-W. Va	950	Campbell, M. R	*Coal*, lime, stone, clay, marble.
27	Morristown	Tenn	963	Keith, A	*Marble*, *stone*, lead, zinc, lime, cement, clay, water.
28	Piedmont	Md.-W. Va	925	Darton, N. H.; Taff, J. A.	*Coal*, iron, lime, stone, road metal, clay.
29	Nevada City special.	Cal	35	Lindgren, W	*Gold*.
30	Yellowstone National Park.	Wyo	3,412	Hague, A.; Weed, W. H.; Iddings, J. P.	National Park; no mining permitted.
31	Pyramid Peak	Cal	932	Lindgren, W	*Gold*.
32	Franklin	Va.-W. Va	932	Darton, N. H	*Iron*, coal, manganese, lime, stone, road metal, clay.
33	Briceville	Tenn	963	Keith, A	*Coal*, *iron*, lead, marble, lime, stone, clay.
34	Buckhannon	W. Va	932	Taff J. A.; Brooks, A. H.	*Coal*, lime, stone, clay.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
35	Gadsden	Ala	986	Hayes, C. W	*Coal, iron*, lime, stone.
36	Pueblo	Colo	938	Gilbert, G. K	*Stone, gypsum*, clay, iron *underground water.*
37	Downieville	Cal	919	Turner, H. W	*Gold*, iron, chromite, lime marble.
38	Butte special	Mont	23	Weed, W. H.; Emmons, S. F.; Tower, G. W.	*Copper, silver*, gold.
39	Truckee	Cal	925	Lindgren, W	*Gold*, silver, coal, stone mineral water.
40	Wartburg	Tenn	963	Keith, A	*Coal, oil*, iron, lime, clay.
41	Sonora	Cal	944	Turner, H. W.; Ransome, F. L.	*Gold*, quicksilver, copper, chromite, lime, stone.
42	Nueces	Tex	1,035	Hill, R. T.; Vaughan, T. W.	Stone, gravel, *underground water.*
43	Bidwell Bar	Cal	919	Turner, H. W	*Gold*, manganese, iron, chromite, stone.
44	Tazewell	Va.-W. Va	950	Campbell, M. R	*Coal*, iron, barite.
45	Boise	Idaho	864	Lindgren, W	*Gold*, silver, coal, diatomaceous earth, stone, clay, underground water.
46	Richmond	Ky	944	Campbell, M. R	Coal, fluorite, phosphate clay, stone, road metal.
47	London	do	950	do	*Coal*, stone.
48	Tenmile district special	Colo	62	Emmons, S. F	*Silver.*
49	Roseburg	Oreg	871	Diller, J. S	Gold, copper, quicksilver, coal, clay, stone.
50	Holyoke	Mass.-Conn	885	Emerson, B. K	Granite, emery, chromite, quartz, road material, sandstone, clay.
51	Big Trees	Cal	938	Turner, H. W.; Ransome, F. L.	*Gold*, silver.
52	Absaroka	Wyo	1,706	Hague, A	Silver.
53	Standingstone	Tenn	963	Campbell, M. R	*Coal*, oil, lime, clay.
54	Tacoma	Wash	812	Willis, B.; Smith, G. O.	*Coal, stone*, clay.
55	Fort Benton	Mont	3,234	Weed, W. H	Gold, *silver*, lead, iron, gypsum, *coal*, stone, underground water.
56	Little Belt Mountains.	do	3,295	do	*Coal, silver*, lead, copper, iron, *sapphires*, mineral water.
57	Telluride	Colo	236	Cross, W.; Purington, C. W.	*Gold, silver.*
58	Elmoro	do	950	Hills, R. C	*Coal*, stone, *underground water.*
59	Bristol	Va.-Tenn	957	Campbell, M. R	*Coal*, iron, zinc, barite, marble, clay.
60	La Plata	Colo	237	Cross, W.; Spencer, A. C.; Purington C. W.	*Gold, silver*, coal.
61	Monterey	Va.-W. Va	938	Darton, N. H	Iron, stone, clay, road metal.
62	Menominee special.	Mich	125	Van Hise, C. R.; Bayley, W. S.	*Iron.*
63	Mother Lode district.	Cal	428	Ransome, F. L	*Gold*, silver, manganese quicksilver, stone.
64	Uvalde	Tex	1,040	Vaughan, T. W	*Asphalt*, gold, silver, iron, coal, underground water
65	Tintic special	Utah	229	Tower, G. W.; Smith, G. O.; Emmons, S. F.	*Gold, silver, lead, copper.*
66	Colfax	Cal	925	Lindgren, W	*Gold*, stone, clay, water.
67	Danville	Ill.-Ind	228	Campbell, M. R; Leverett, F	*Coal*, clay, gravel, underground water.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
68	Walsenburg	Colo	944	Hills, R. C	*Coal*, stone, clay, *underground water*.
69	Huntington	W. Va.-Ohio	938	Campbell, M. R	*Coal*.
70	Washington	D. C.-Va.-Md.	465	Darton, N. H.; Keith, A.	Gold, iron, clay, stone, road materials, greensand marls, *underground water*.
71	Spanish Peaks	Colo	950	Hills, R. C	*Coal*, stone, gold, silver, *underground water*.
72	Charleston	W. Va	938	Campbell, M. R	*Coal, salt, oil, gas*, iron.
73	Coos Bay	Oreg	871	Diller, J. S	*Coal*, gold, stone.
74	Coalgate	Ind. T	980	Taff, J. A	*Coal*, stone, clay.
75	Maynardville	Tenn	963	Keith, A	*Marble*, coal, stone, lead, zinc, lime, road materials, clay.
76	Austin	Tex	1,030	Hill, R. T.; Vaughan, T. W.	Oil, stone, lime, clay, cement rock, underground water.
77	Raleigh	W. Va	944	Campbell, M. R	*Coal*.
78	Rome	Ga.-Ala	986	Hayes, C. W	*Bauxite, iron, slate*, lime.
79	Atoka	Ind. T	986	Taff, J. A	*Coal*, stone, clay.
80	Norfolk	Va.-N. C	1,913	Darton, N. H	Sand, clay, *underground water*.
81	Chicago	Ill.-Ind	892	Alden, W. C	*Stone*, clay, molding sand, water.
82	Masontown-Uniontown.	Pa	458	Campbell, M. R	*Coal, oil, clay*, stone, glass sand, iron.
83	New York City	N. Y.-N. J	906	Merrill, F. J. H.; Hollick, A.; Darton, N. H.; Willis, B.; Salisbury, R. D.; Dodge, R. E.; Pressey, H. A.	*Marble*, granite, *road material*, clay, iron, water.
84	Ditney	Ind	938	Fuller, M. L.; Ashley, G. H.	*Coal*, gas, clay, stone, iron.
85	Oelrichs	S. Dak.-Nebr.	871	Darton, N. H	Stone, gypsum, lime, volcanic ash, *underground water*.
86	Ellensburg	Wash	820	Smith, G. O	Building stone, road metal, *ground water, underground water*.
87	Camp Clarke	Nebr	892	Darton, N. H	Volcanic ash.
88	Scotts Bluff	do	892	do	Do.
89	Port Orford	Oreg	878	Diller, J. S	*Coal*, gold, platinum.
90	Cranberry	Tenn	963	Keith, A	Mica, gold, brick clay, *iron ore*.
91	Hartville	Wyo	885	Smith, W. S. T	*Iron ore*, copper, lime, building stone, gypsum, fire clay.
92	Gaines	Pa.-N. Y	223	Fuller, M. L.; Alden, W. C.	*Oil*, coal.
93	Elkland-Tioga	Pa	445	do	Flagstone, lime, gravels.
94	Brownsville-Connellsville.	do	457	Campbell, M. R	*Coal, natural gas*.
95	Columbia	Tenn	969	Hayes, C. W.; Ulrich, E. O.	*Phosphate*, iron.
96	Olivet	S. Dak		Todd, J. E	Granite, lime, quartzite, underground water.
97	Parker	do	871	do	Quartzite, chalk, cement rock, underground water.
98	Tishomingo	Ind. T	986	Taff, J. A	Granite, lime building stone, clay.
99	Mitchell	S. Dak	863	Todd, J. E	*Underground water*, sandstone, chalkstone.
100	Alexandria	do	863	Todd, J. E.; Hall, C. M.	*Underground water*, quartzite, sandstone, chalkstone.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
101	San Luis	Cal	975	Fairbanks, H. W	*Bituminous rock*, building stone, road metal, chrome iron, hematite, manganese, pumice, infusorial earth.
102	Indiana	Pa	237	Richardson, G. B	*Coal, gas, fire clay,* brick clay, building stone.
103	Nampa	Idaho		Lindgren, W.; Drake, N. F.	Gold, coal, *opals,* building stone.
104	Silver City	do	871	do	*Gold, silver,* coal, opals.
105	Patoka	Ind.-Ill	938	Fuller, M. L.; Clapp, F. G.	Coal, gas, oil, asphalt, fire clay, brick clay, building stone, gravel.
106	Mount Stuart	Wash	805	Smith, G. O	*Gold,* copper, silver, nickel, quicksilver, *coal,* stone, road metal.
107	Newcastle	Wyo.-S. Dak	864	Darton, N. H	*Coal,* petroleum, *gypsum,* bentonite, salt brines, stone, underground water.
108	Edgemont	Nebr.-S. Dak.	871	Darton, N. H.; Smith, W. S. T.	Water supply, coal, gypsum, stone, grindstones, underground water.
109	Cottonwood Falls	Kans	938	Prosser, C. S.; Beede, J. W.	Building stone, clay, road metal.
110	Latrobe	Pa	228	Campbell, M. R	*Coal,* natural gas, building stone, *glass sand,* paving blocks, ballast, lime, salt, *fire clay.*
111	Globe	Ariz	249	Ransome, F. L	*Gold, silver, copper,* lead, lime, building stone, *underground water.*
112	Bisbee	do	170	do	*Copper,* gold, lead, clay, silica, building stone, *underground water.*
113	Huron	S. Dak	857	Todd, J. E	Building stone, clay, sand, gravel, *underground water.*
114	De Smet	do	857	Todd, J. E.; Hall, C. M.	Clay, sand, gravel, underground water.
115	Kittanning	Pa	226	Butts, C.; Leverett, F.	*Coal, oil, gas, clay,* lime, iron, building stone, sand.
116	Asheville	N. C.-Tenn	969	Keith, A	*Talc,* soapstone, *barite,* corundum, garnet, magnetite, iron, marble.
117	Casselton-Fargo	N. Dak.-Minn.	1,640	Hall, C. M.; Willard, D. E.	*Underground water.*
118	Greeneville	Tenn.-N. C	963	Keith, A	*Marble,* building stone, road metal, iron, lime, brick clay.
119	Fayetteville	Mo.-Ark	963	Adams, G. I.; Ulrich, E. O.	Clay, building stone, lime, coal.
120	Silverton	Colo	236	Cross, W.; Howe, E.; Ransome, F. L.	*Gold, silver, copper, lead,* zinc, iron, lime, building stone.
121	Waynesburg	Pa	229	Stone, R. W	*Coal, gas, oil,* building stone, lime, clay, iron, underground water.
122	Tahlequah	Ind. T.-Ark	969	Taff, J. A	Building stone, lime, clay.
123	Elders Ridge	Pa	227	Stone, R. W	*Coal, gas,* oil, building stone, lime, fire clay, stoneware clay.
124	Mount Mitchell	N. C	969	Keith, A	Soapstone, *talc,* mica, precious stones, corundum, graphite, iron, chromite, *building stone,* lime, brick clay.
125	Rural Valley	Pa	226	Butts, C	*Coal,* oil, *gas,* fire clay, iron ore, lime sandstone.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
126	Bradshaw Mountains.	Ariz	986	Jagger, T. A., jr.; Palache, C.	*Gold*, *silver*, copper, iron, building stone, onyx marble.
127	Sundance	Wyo.-S. Dak.	857	Darton, N. H.	Gold, *tin*, silver, lead, *coal*, gypsum, bentonite, *underground water*.
128	Aladdin	Wyo.-S. Dak.-Mont.	894	Darton, N.H.; O'Harra, C. C.	*Underground water*, coal, gypsum, lime.
129	Clifton	Ariz	250	Lindgren, W.	*Copper*, iron, lead, gold, kaolin.
130	Rico	Colo	236	Cross, W.; Spencer, A. C.; Ransome, F. L.	*Gold*, *silver*, zinc, lead, building stone, lime.
131	Needle Mountains	Colo	236	Cross, W.; Howe, E.; Irving, J. D.; Emmons, W. H.	Gold, silver.
132	Muscogee	Ind. T.	969	Taff, J. A.	Oil, *coal*.
133	Ebensburg	Pa	228	Butts, C.	*Coal*, clay, shale, building stone, underground water.
134	Beaver	Pa	227	Woolsey, L. H.	*Clay*, coal, *oil*, gas, building stone.
135	Nepesta	Colo	938	Fisher, C. A.	Cement, iron ore, oil, gas, gravel.

6. *Mineral Resources of the United States.*—From 1883 to 1894, inclusive, an octavo cloth-bound volume bearing the above title was issued annually, except that the reports for the years 1883-84 and 1889-90 were included by pairs in single volumes. The first of this series was Mineral Resources of the United States, 1882; the last, Mineral Resources of the United States, 1893. In 1894 this form of publication was discontinued, in accordance with an act of Congress, and the statistical material was included in certain parts of the sixteenth, seventeenth, eighteenth, nineteenth, twentieth, and twenty-first annual reports. The separate publication of the series on mineral resources was resumed, however, in 1901, in accordance with an act of Congress, and five volumes of the new series, Mineral Resources of the United States for 1900, for 1901, for 1902, for 1903, and for 1904 have been issued.

This publication contains a systematic statement of the production and value of the mineral products of the United States, a summary of new mineral resources developed, and occasional short papers on economic geology when these are necessary to account for the new developments.

INVESTIGATION OF METALLIFEROUS ORES.

By S. F. **Emmons**, *Geologist in Charge.*

ECONOMIC PUBLICATIONS OF THE YEAR.

During the year the number of Survey publications on subjects connected with the investigation of metalliferous ores within the United States proper was somewhat smaller than during previous years. This has resulted less from the falling off of the amount of work done in that line by members of the Survey than from other causes, among which should be mentioned, first, the fact that several economic geologists have resigned from the Survey to accept more remunerative positions elsewhere, which has so far reduced the available force; second, the administrative investigations intended to improve the service of the Government Printing Office, but whose immediate effect has been to delay temporarily the printing of the Survey reports. The following publications on metalliferous investigations have been issued during the year 1905:

Professional Papers:

No. 36. Lead, zinc, and fluorspar of western Kentucky, by E. O. Ulrich and W. S. Tangier-Smith.

No. 38. Economic geology of the Bingham mining district, Utah, by J. M. Boutwell, Arthur Keith, and S. F. Emmons.

No. 42. Geology of the Tonopah mining district, Nevada, by J. E. Spurr.

No. 43. Copper deposits of Clifton-Morenci district, Arizona, by Waldemar Lindgren.

Bulletins:

No. 246. Zinc and lead deposits of northwestern Illinois, by H. F. Bain.

No. 253. Fluorspar deposits of southern Illinois, by H. F. Bain.

No. 267. Copper deposits of Missouri, by H. F. Bain and E. O. Ulrich.

Folios:

No. 120. Silverton quadrangle, Colorado, by Whitman Cross, Ernest Howe, and F. L. Ransome.

No. 126. Bradshaw Mountains quadrangle, Arizona, by T. A. Jaggar, jr., and Charles Palache.

No. 129. Clifton quadrangle, Arizona, by Waldemar Lindgren.

Unpublished studies.—(1) Studies of which the field and office work have been entirely completed and the reports written by the authors, in different stages of completion for final publication:

Professional papers:

The geology and gold deposits of the Cripple Creek district, Colorado, by Waldemar Lindgren and F. L. Ransome.

Ore deposits of the Silver Peak quadrangle, Nevada, by J. E. Spurr and G. H. Garrey.

Ore deposits of the Cœur d'Alene district, Idaho, by F. L. Ransome and F. C. Calkins.

Copper deposits of the Appalachian region, by W. H. Weed.

Bulletin:

Reconnaissance of some gold and tin deposits of the Southern Appalachians, by L. C. Graton, with notes on the Dahlonega mines, by Waldemar Lindgren.

(2) Studies for which the field work has been completed and whose manuscript is in more or less advanced stages of completion by the authors:

Ore deposits of the Georgetown mining district of Colorado, by J. E. Spurr and G. H. Garrey.

Economic geology of the Park City mining district of Utah, by J. M. Boutwell.

Copper deposits of the Butte district, Montana, by W. H. Weed.

Resurvey of the Leadville mining district of Colorado, by S. F. Emmons and J. D. Irving.

Advance notices of most of the above reports have already appeared in previous numbers of the Economic Bulletin in the form either of abstracts or of preliminary reports on the results of the field work. Where this has not been done, or where the final publication of the report has been long delayed, there has been some good reason therefor which may not always be apparent to the public.

The survey of the Park City mining district has disclosed unexpected structural complications in the geology which promise to have an important influence on the mining development of the region and demand a correspondingly great amount of care and detail in their working out. Other duties to which he has from time to time been assigned have, furthermore, taken a certain amount of Mr. Boutwell's time from this work. That he might push it to completion with the shortest possible delay, Mr. Boutwell undertook no field work whatever during the past year, but spent the entire summer in office work on this report, which it is expected will be completed before the opening of another field season.

For a number of years past there has been in preparation a detailed study of the complicated vein systems of the copper district of Butte, which will constitute the most important record yet made of the manner of formation of copper in veins in granite, their subsequent faulting by a new system of secondary veins, and the sulphide enrichment of both systems by descending waters. This record is of relatively small importance to the immediate development of the district, its greatest value being to the mining world in general as an illustration of the typical development of this important class of copper deposits. Completeness of the record has, therefore, been of more importance than early publication, especially as, pending the settlement of the many lawsuits in regard to property rights in the district, the Survey report might exercise an unfavorable influence on one side or another on the questions at issue; hence Mr. Weed's work on this report has been put aside from time to time to admit of his carrying on other investigations whose publication seems of more immediate importance to the mining public. In view of the recent important underground discoveries at Butte, this delay has proved to be most wise, since it will have rendered the record far more complete than it could otherwise have been. It is intended, however, that the report shall now be prepared for the earliest possible publication.

In the case of the resurvey of the Leadville district, whose long delay has not unnaturally been the cause of some unfavorable comment, the conditions governing its publication are more difficult to explain, especially to those who are not practically familiar with the actual mining work and manner of occurrence of ore in the district and with the peculiar methods which consequently have to be pursued in making a geological map there. The ordinary method of making a geological map of a given area is to carefully examine its surface and enter on the map the outlines of the different rock formations, with their dips and strikes, supplementing this with what data may be obtained from the underground workings of the mines or their artificial excavations. Thus, in order to depict the underground structure, the surface outcrops are, so to speak, projected downward. In the Leadville district, however, practically no information is derived from the surface, and the geological outlines represented on the surface map must be made by projecting upward to the surface the information obtained in studying the underground workings of the mines. This, although more laborious, is a very practicable method, provided only that the underground workings extend nearly continuously over the whole area. This is unfortunately not the case at Leadville, for although in certain portions, where the ore bodies are concentrated, mine drifts honeycomb the rocks in all directions, there are considerable areas where ore has not been found or which are practically unexplored underground. Even in the explored areas there are gaps in possible information where extensive mines have been abandoned and their drifts have become inaccessible, with regard to which no accurate geological data can, therefore, be obtained. With each new mining development portions of these gaps are filled up, and when the mines are visited while still open and accessible the information gathered adds to that already obtained with regard to the actual underground structure of the district. Thus, since starting the review of the Leadville work in 1890, the writer has made visits to the region every year or two to gather such new data, but causes beyond his control have rendered it impossible for him to have compiled at any given period the material already gathered in form for publication. These recent studies have shown that the broad outlines of geological structure, as given on the original maps of the region, are substantially correct. The modifications of them that the new data will necessitate are such as no human foresight could have predicated, consisting mainly of faults and intrusive sheets of which no indication could be seen at the surface or in the underground workings then accessible. On these early maps much of the underground structure shown was necessarily inference and some pure surmise. On the new maps it is desired to restrict the area of inference and surmise as much as possible. Inasmuch as the manner of occurrence of the ore is thoroughly understood by Leadville miners, the principal value of the present review will be to afford a picture of the ground already opened and it can not be expected to show very much that is new with regard to ground that has not been opened; hence, while the work has not been intentionally delayed, the delay that has occurred has added greatly to its value. It can, in the nature of things, be of little use in determining the position of undiscovered ore bodies, but it may afford means of estimating more nearly the area of possible extension of ore-bearing horizons in some parts of the region, such as those that are buried beneath several hundred feet of wash. It is the present intention of the writer to publish smaller preliminary maps of such areas as can be prepared without waiting till the accumulated data are sufficient for the accurate reconstruction of the map of the entire district.

ECONOMIC WORK IN PROGRESS DURING THE YEAR.

GENERAL DISCUSSION.

An important step has been taken during the year toward rendering the economic work of the Survey more comprehensive and efficient by instituting a closer cooperation between the section of metalliferous ores and the division of mineral statistics. To this end, early in the year, the supervision of the collection of statistics of the precious metals was placed in charge of Mr. Waldemar Lindgren, of the former section, who thus assumed, besides his regular work, a very considerable addition of labor in reorganizing and improving the method of collection hitherto pursued. Some of the shortcomings in the previous method have been pointed out in a former number of this bulletin. The amelioration that can be expected from the supervision of the work by a man like Mr. Lindgren, who combines long experience in all the details of the precious-metal industry with a profound knowledge of the geological relations of their deposits, will be important, even more than in furnishing accurate statistics of the total production of the country, for segregating the proportions of that production, not only among States and counties but among districts, and in furnishing at the same time sufficient geological data with regard to the less known districts to render possible an annual discussion of the precious-metal industry with reference to its geological distribution. But of more immediate importance to those actively interested in mining will be the fact that with regard to individual mining districts, especially those that are new or little known, the investor in mines can feel sure that the information furnished is given by men who are not only competent to speak with authority from a technical point of view but that what they say is wholly unbiased and free from even the suspicion of any personal interest that might make them consciously or unconsciously regard the future in too favorable a light.

The beneficial results of this change in method can not be fully appreciated until the mineral statistics for the year 1905 shall have been published, but an improvement is already noticeable in those for the year 1904, in which, although the actual figures had been collected before he took charge, Mr. Lindgren was enabled to introduce decided improvements in the methods of presentation of facts and their discussion.

When this method of treating statistics shall have been extended to the other metals the discussion of the results from the geological standpoint will form an important part of the work of the section of metalliferous ores.

The work more strictly belonging to this section (excluding that in Alaska) that has been carried on during the year will be noted in geographic order:

UNITED STATES IN GENERAL.

Mr. W. H. Weed has compiled from certain publications a general review of the important copper deposits of the United States which will, it is thought, be found of value to all interested in mines as furnishing in condensed form the geological data necessary for an understanding of the manner of occurrence of the principal copper-producing ores.

APPALACHIAN REGION.

Mr. Weed has continued from time to time during the year his reconnaissance studies of the copper deposits of the Appalachian region, the manuscript of which, as already noted, is very nearly ready for publication, and it is hoped that it will be issued very shortly after the appearance of the present bulletin.

Mr. Spencer has carried on during the summer a special study of the geological relations of the magnetite deposits of the Franklin Furnace quadrangle, in New Jersey, with the idea that the solution of this problem may throw important light on the mooted question of the origin of the Franklin Furnace zinc ores.

Mr. Charles Palache has been occupied during the same time in making a mineralogical study of the Franklin Furnace ores, which it is hoped will also throw some light on their genesis.

MISSISSIPPI VALLEY REGION.

At the commencement of the field season Mr. Bain, who has hitherto had charge of the work in this region, resigned his position on the Survey to accept the directorship of the Illinois State Geological Survey; consequently, no economic field work has been carried on in this region during the year.

As reconnaissance examinations, in intervals of other work, Mr. E. O. Ulrich has examined the copper deposits in sedimentary rocks that are of widespread occurrence in northern Texas. Mr. G. B. Richardson has also studied the geological relations of the tin deposits of the Franklin Mountains, near El Paso, the results of which appear in this bulletin.

ROCKY MOUNTAIN REGION.

Arizona.—The work planned for Arizona for the field season had been an economic survey of the Tombstone mining district and reconnaissance examinations of the smaller mining districts of the Territory by Mr. F. L. Ransome and his assistants. When, however, at the commencement of the field season, Mr. Spurr resigned his position on the Survey, it was judged best to assign Mr. Ransome to the economic survey of the Goldfield and Bullfrog districts of Nevada, which originally had been allotted to Mr. Spurr; hence, the field work that has been done in Arizona during the year has consisted only of visits by the writer to the Tombstone, Bisbee, and Globe districts for the purpose of keeping in touch with geological phenomena newly exposed in these regions by recent mining developments.

Colorado.—In Colorado a geological field party has been engaged during the summer in mapping more carefully the geology of portions of northwestern Colorado, which will be opened by the new "Moffatt road" that is destined to connect Denver with Salt Lake City. In the course of this work, Mr. H. S. Gale was enabled to make a reconnaissance examination of the Hahns Peak gold field and map its geology. His report on this district is included in the present volume.

In continuation of the work already commenced in Clear Creek and Gilpin counties, Mr. Spurr was able to spend ten days, and his assistant, Mr. G. H. Garrey, spent six weeks in studying the mines in the vicinity of Idaho Springs. A preliminary report by Mr. Garrey on the results of this work will be found later in this volume.

In western Colorado, as part of a reconnaissance made of the region south of the La Sal Mountains by Mr. Cross's party, Mr. W. H. Emmons examined some interesting copper deposits in veins traversing Mesozoic rocks, and contributes a report thereon to the present volume. The same geologist presents an abstract of his report on the mines of the Needle Mountain quadrangle, in the southern San Juan Mountains.

Idaho.—In Idaho considerable reconnaissance work has been done in the region both to the north and to the south of the Cœur d'Alene district, the field work of which was completed by Mr. Ransome and his assistants during the field season of 1904.

Mr. D. F. MacDonald, former assistant of Mr. Ransome, made an extensive geological reconnaissance of the country stretching for a hundred miles north of the Cœur d'Alene, including portions of northern Idaho and northwestern Montana, and submits in the present volume a report on his observations with special reference to their economic bearing.

Mr. Collier, who was for several years previous engaged in geological work in the Alaskan division, also submits a report on the metallic resources of the region immediately adjoining the Cœur d'Alene district on the south.

Montana.—Late in the year Mr. Weed made a visit to Butte, Mont., to study the important new developments recently made in the copper veins of this great district, which thus completes his record for the exhaustive report which he is preparing on its copper deposits.

Nevada.—The attention of the mining public has been for the past few years especially directed to Nevada because of the unusually rich gold ores found in the newly discovered districts, such as Tonopah, Goldfield, Bullfrog, and others. A proportionately larger portion of the economic work of the Survey has, therefore, been done in this State to meet the demand for information with regard to its geological structure. Special topographic maps had already been prepared of the Goldfield and Bullfrog districts, and Mr. Spurr, who had made the survey of the Tonopah district, was originally assigned to the economic examinations of these districts. After Mr. Spurr's resignation from the Survey Mr. Ransome took charge of the work, having as assistants Mr. G. H. Garrey, who had previously been working with Mr. Spurr, and Mr. W. H. Emmons. He was, however, unable to take the field until September, and owing to delays incident on the unexpected difficulty of the work and the unusually severe winter weather the field work, which has been made to include also a reconnaissance of the Searchlight district, is only just completed—too late to admit of the preparation of any preliminary report for this volume.

During the past field season a party under Mr. R. H. Chapman has been engaged in making a topographical survey of the portions of the Great Basin region in southern Nevada and eastern California that include the new mining developments. To this party Mr. S. H. Ball was attached, as geologist, to make such geological surveys of the region as was possible during the relatively rapid movements of the topographic party. In the course of this work he was enabled to visit a number of smaller mining districts and note their geological structure and such facts with regard to their ore deposits as could be ascertained at the present stage of their development. His notes on these districts, although the geological information they afford is necessarily somewhat meager, are published in this volume, in response to the popular demand for early information with regard to new districts. It must be borne in mind, however, by those who have made these demands, that the geologist can not see any farther into a rock than any other man; he can only draw inferences from what is exposed to view, and the deeper the exposure the greater its value for such inferences, since surface alteration of the rocks so obscures their true character as to render their determination very uncertain. As this surface alteration often extends for a considerable depth below the actual surface, it is only when he can extend his studies to a depth that is beyond the reach of surface alteration that the geologist can determine the true character of the rocks with sufficient certainty to render his inferences of permanent value.

Zinc mines are of rather exceptional occurrence in Nevada, and this fact adds interest to the report of Mr. Bain, to be found on later pages of the present volume, on the Potosi mine, in which he finds certain analogies with the zinc deposits of the Mississippi Valley region.

New Mexico.—The Territory of New Mexico is rich in mineral deposits, but as yet no great mining districts comparable to Butte and Cripple Creek have been developed within its boundaries and no detailed economic studies have hitherto been made there by the Survey. It has, however, a great number of smaller mining districts of geological interest and of considerable economic importance.

During the past summer reconnaissance examinations of all these districts have been made in as much detail as the want of actual topographic surveys will admit. This work has been under the charge of Mr. Waldemar Lindgren, who has been assisted by Messrs. L. C. Graton and C. H. Gordon. A preliminary report of the results of their work has been prepared for this volume.

Texas.—The Franklin Mountains, just north of El Paso, though within the political boundaries of Texas, belong more properly to the physiographic province of New Mexico. The occurrence of tin ores in these mountains has long been known and a short description of them by Mr. W. H. Weed was published in Bulletin No. 178. During the past summer Mr. G. B. Richardson made a reconnaissance examination of the geology of the entire range and incidentally reexamined the tin deposits. His report is to be found on later pages of this bulletin.

Utah.—No systematic economic field work has been done in the State of Utah during the present season. A special survey of the region around Frisco, in the southern part of the State, including the Horn Silver, Cactus, and other mines, had been planned and the topographic basis for the same was already prepared; but, owing to the reduction in the number of available economic geologists, there was no one to carry on the work and it has therefore been postponed until another season.

Mr. Lindgren visited the State in the interest of his work on statistics of the precious metals and incidentally made an examination of the Annie Laurie gold mine, in the vicinity of Marysvale, in the southern part of the State. His report, which appears later in this volume, will be of interest as the description of an important gold mine in a district of whose geology little has hitherto been known.

INVESTIGATION OF IRON ORES AND NONMETALLIFEROUS MINERALS.

By Edwin C. Eckel, *Geologist in Charge.*

INTRODUCTION.

The work which can be carried on by the Survey in the investigation of iron ores and the nonmetallic products differs very markedly from that which is either required or practicable in the examination of gold, silver, copper, lead, and zinc deposits. The differences between the two lines of work are based on fundamental differences between the products treated. In the one case we have usually to deal with small bodies of ore of high unit value occurring at scattered localities and requiring little else than mining to make it a valuable product. In dealing with iron ores and the nonmetals, on the other hand, we encounter minerals of low unit value, widely distributed over the country and usually occurring in large bodies, whose industrial value depends chiefly on nongeologic factors, such as composition, transportation, facilities, milling methods, etc.

These facts have influenced the work of the Survey in dealing with iron and the nonmetals in two ways. First, a proper report on such products requires very careful detailed stratigraphic and areal work and can hardly be undertaken profitably unless a satisfactory topographic base is available. Second, the products owe so much of their possible value to purely technologic and industrial conditions that a complete report on them requires consideration of many subjects not directly connected with the geology of the deposits. For this reason Survey reports on the iron ores, fuels, structural materials, etc., must necessarily contain matter relative to the industrial relations of these products, which is not necessary in reporting, for example, on a deposit of high-grade gold ore. The economic work, furthermore, must generally be carried on in close connection with detailed areal and stratigraphic examinations; and for the best results a very accurate topographic base is essential.

A further essential difference between the work possible on the two classes of products lies in the fact that, in general, the geologist can point out, in advance of actual exploration, where workable deposits of limestone, clay, coal, and iron ore are likely to occur. Furthermore, in many cases he can make a close estimate of the total tonnage available in any area—an estimate which would be impossible in dealing with gold, copper ores, etc. It is probable, for example, that a careful geological examination of a southern red-hematite district would enable the geologist to estimate the total quantity of ore with a limiting error of less than 10 per cent, and this is a grade of accuracy very different from that possible in dealing with the irregular bodies in which the ores of gold, silver, copper, lead, and zinc usually occur.

IRON, MANGANESE, AND ALUMINUM ORES.

Iron ores.—For many years past the Lake Superior district has furnished two-thirds of the iron ore produced in the United States. The geologic problems connected with these ore deposits are of great complexity, and the importance of the subject naturally caused this to be the first iron-ore district to be taken up in a detailed way by the Survey. A series of reports on the various lake ore ranges have been published, and as the detailed mapping of that district is now practically completed work is being commenced on the iron-ore deposits of the Southern and Western States.

Several Survey parties were engaged in the examination of Alabama iron districts during 1905. Mr. Butts, with the assistance of Mr. Dawson, completed areal and economic mapping of a large part of the important Birmingham district and collected data on the "Clinton" red ores of that region. Mr. E. C. Eckel examined the red-ore deposits in the Lookout Mountain district from Chattanooga to Attalla, Gadsden, and Gaylesville, and later visited the brown-ore districts, of which Anniston is the center. Arrangements have been made for cooperative work with the Alabama Geological Survey, and reports on the iron ores and iron industries of Alabama will be issued as soon as possible. The present bulletin contains a brief preliminary report on the red ores of the Lookout Mountain district.

In Virginia work on the iron ores was carried on in cooperation with the Virginia Geological Survey, the field work being divided between the two organizations. Mr. R. J. Holden, of the Virginia Survey, examined the brown ores of the New River-Cripple Creek district and later spent some time in the Oriskany district. Mr. E. C. Eckel examined most of the Oriskany and Clinton ores of the State, with the assistance of Mr. J. S. Grasty. Prof. H. D. Campbell placed his detailed maps of the district at our disposal, which rendered possible a very complete report on the district. In this bulletin (pp. 183 and 190) preliminary reports on several Virginia iron districts are presented.

A brief paper on the ores of Bath County, Ky., is included, the report being based on data obtained by Messrs. Kindle and Phalen in the course of areal mapping in that district.

The recent extension of actual development as well as of detailed exploration of the new ore deposits of the Rocky Mountain and Pacific States has made it evident that these deposits may prove to be important factors in the iron industry of the future. Mr. C. K. Leith examined most of the developed districts during the past year, and his report, presented later in this bulletin, is a valuable preliminary statement on the subject. Detailed work on these iron ores will be taken up by the Survey as soon as possible.

Mr. A. C. Spencer has for some time been engaged in a very detailed study of the iron, zinc, and manganese deposits of the Franklin Furnace district of New Jersey. In connection with this work he has examined a number of magnetite deposits elsewhere in New Jersey and in New York, and has formulated theories of occurrence and origin which seem to have an important bearing on the future development of these ores. The exploratory work so far carried on by mining companies has been of a rather haphazard nature, based on no definite working theory. It is hoped that the publication, during 1906, of Mr. Spencer's report will supply the prospector and miner with data which will serve as a guide both in locating and valuing the deposits.

Manganese.—As most of the manganese ores of the United States are closely associated, both geographically and geologically, with brown-iron ores, work on the two products is best carried on by the same Survey parties. In the course of the work on the southern iron ores outlined on a previous page considerable data have been collected concerning the manganese ores of Virginia, Georgia, and Alabama.

Aluminum.—During 1905 bauxite was discovered in Tennessee, Virginia, and Pennsylvania, far to the north of the previously known occurrences. Developments in the use of low-grade bauxite for the manufacture of refractory brick have also stimulated interest in the industry, so that prospecting for bauxite has been particularly active during the past year. It is noteworthy, however, that though these new discoveries extended the area known to contain bauxite deposits, the general location and character of the deposits are entirely in line with the conditions pointed out by Survey geologists a decade ago. During 1905 the Arkansas deposits were reexamined by Survey parties, and it is probable that in 1906 the new eastern districts will be surveyed and reported on.

FUELS AND OTHER HYDROCARBONS.

The great activity in the investgation of the fuel resources of the country which was noted in "Contributions to Economic Geology" for 1904 was continued and considerably extended during the season of 1905. This extension was due in large measure to the general interest which was taken in the investigations carried on by the fuel-testing division and to a large amount of geologic work in the coal fields of the country, which was made possible by an increase in appropriations.

Coal.—To coordinate the geologic work in various parts of the country, Mr. M. R. Campbell was directed to exercise supervision over the investigations of coal resources throughout the United States. Although Mr. Campbell's work was to include the entire country, it was understood that he was to give particular attention to the Rocky Mountain region, and that in connection with the regular geologic work he was to cooperate with the coal-testing plant at St. Louis by securing samples of coal to be tested.

In the Appalachian region geologic work was carried on at three localities—western Pennsylvania, eastern Kentucky, and central Alabama. In Pennsylvania about 750 square miles of coal territory was surveyed in great detail. In eastern Kentucky an area of about 950 square miles was thoroughly examined; and in Alabama a part of the coal field, about 500 square miles in extent near the city of Birmingham, was also examined with great care.

In the Rocky Mountain region a number of coal fields have been attracting the attention of coal operators and railroad men for some time. Reconnaissance surveys were made over several of these fields in order to provide the public with information in advance of active development in railroad construction. A large part of the Durango-Gallup field in southern Colorado and northwestern New Mexico, covering an area of about 2,000 square miles, was studied, and the various coal groups were mapped. Similar work, though perhaps in greater detail, was done over the larger part of the Yampa coal field of Routt County, northwestern Colorado. Great activity has been manifested in this field lately through the prospective building of the Denver, Northwestern and Pacific Railway through this field. The coals generally are of the bituminous variety, but in the northern part of the field there is a small area in which the coal has been converted to anthracite. This is due to local metamorphism, and the field is consequently of limited extent.

In Utah an attempt was made to examine the entire coal-bearing areas of the State in cooperation with the General Land Office. The shortness of the season permitted an examination only of the Book Cliffs area from the Sunnyside mine westward and also of the small coal field in the vicinity of Coalville. The Book Cliffs field is of great importance, and the maps and report prepared during this survey will doubtless be of great value. In addition to the regular systematic work on the Book Cliffs field some information was also obtained regarding coals in San Pete County. These are small outlying areas, and probably never will be of great value except for local use.

In Wyoming special attention was given to the coal fields of the southwestern part of the State in what is generally known as the Hams Fork coal field. This was examined with great care, with the object of determining both the fuel value and geographic distribution of the coals, as well as the amount of unclaimed coal land still remaining in the field. Incidentally considerable data were obtained regarding the coal field of the Bighorn basin, but this was done in connection with the investigation of underground water, and consequently was not of so detailed a character as the work just mentioned.

In North Dakota and Montana the work already begun by the North Dakota Geological Survey was extended so as to cover the valley of Little Missouri River south of the Northern Pacific Railway and the territory west into Montana. In the latter State reconnaissance work was carried on from the mouth of Yellowstone River as far up as Miles City. Heretofore the brown lignites of this region have not been regarded as particularly valuable for fuel purposes, but the tests made at the Government coal-testing plant on brown lignites as a fuel for the manufacture of producer gas show such excellent results that it seems possible that these low-grade fuels may become extremely valuable in the near future for the production of power. The geologic work was done in anticipation of a greater demand for this class of fuel.

Oil and gas.—Comparatively little work was done during the year 1905 on the oil fields of the country. In the Appalachian region Mr. Griswold continued his close structural studies, making very accurate and detailed maps of the oil-bearing sands of a part of western Pennsylvania. In California Mr. Arnold has taken up the work of Mr. Eldridge and during the latter part of the year has been engaged in an attempt to determine the conditions which control the accumulation of the heavy oil of California, so as to be able, if possible, to assist the driller in possible extensions of the old fields and in the discovery of new fields where oil is at present unknown.

Asphalts.—A report by Mr. Taff on the important ozokerite deposits of Utah is included in the present bulletin, the report being based on work done in 1905.

STRUCTURAL MATERIALS.

Cement.—In the summer of 1905 Mr. R. S. Bassler spent several months in western and southwestern Virginia examining and sampling the various limestone and shale deposits of that portion of the State. The important beds of shaly limestone ("cement rock") which form the basis of the Portland cement industry of the Lehigh district (Pennsylvania-New Jersey) were found to occur at many localities in the Shenandoah Valley, and these areas were carefully mapped and sampled. The results of this work will appear later as a report on the "Cement Resources of the Valley of Virginia."

Later in the season Mr. Eckel examined the cement prospects in the vicinity of Cumberland Gap (Tennessee-Virginia-Kentucky), where heavy beds of nonmagnesian limestone and shale outcrop in close proximity to the important Middlesborough coal field and where transportation facilities are satisfactory. His conclusions are stated in a brief report, in the present bulletin, on the "Cement Resources of the Cumberland Gap District."

Lime.—The most important lime-producing district of the eastern United States is that located in Knox County, Me., including the two well-known lime-burning localities, Rockland and Rockport. During the past season Mr. E. S. Bastin made a careful geologic survey of this district, and a report on his results is contained in the present bulletin. In this report Mr. Bastin shows the close relation of the geologic structure of the region to its economic importance. Obviously, in any search for good limestone beds, intelligent exploration must be based on a thorough knowledge of the geology of the limestones. In a folio now in preparation these facts will be taken up in more detail. Mr. Bastin's report is the first paper—since 1840 or thereabouts—which presents data of value on either the geologic or the technologic features of the Rockland lime industry.

Magnesite.—In the fall of 1905, on his return from Alaska, Mr. Frank Hess was enabled to spend a short time in the examination of the magnesite deposits of California. His report, which is published elsewhere in this bulletin, is a notably clean-cut piece of work, which marks a distinct advance in our knowledge of not only the geology but the technology of magnesite. The California magnesite deposits are, so far as now known, the only workable bodies of this mineral in the United States. High freight rates prevent their product from reaching the eastern market, so that the magnesia-brick plants of Pennsylvania and Ohio employ imported (Grecian and Austrian) magnesite exclusively.

The technology of magnesite is so imperfectly understood, even by the manufacturers who use the material, that investigations are now being carried on in the Survey laboratory to determine such important points as burning temperatures, relation of temperature to loss of carbon dioxide, relation of physical character to burning phenomena, etc. The results of this work will doubtless be of value to those interested in the American magnesite industry. Such investigations can rarely be carried on by any individual manufacturer, for few commercial laboratories possess the facilities necessary for accurate work at high temperatures.

Gypsum.—In the course of Survey work in the Western States a certain amount of data on their gypsum deposits have been collected. The present bulletin contains a brief report by Mr. C. E. Siebenthal on the gypsum of the Laramie district of Wyoming.

Stone.—Two important pieces of work on the building stones of the United States were taken up in 1905 by the Survey. The first was the preparation, by Prof. T. Nelson Dale, of a report on the "Slate Deposits of the United States." This is now in press and will be published in 1906 as Survey Bulletin No. 275.

Professor Dale also commenced work on the granite deposits of eastern United States. During 1905 he made a very careful examination of all the Maine granite districts, and his report on that State will be submitted before the close of 1906.

An event of great interest to the stone industry is described briefly in Professor Dale's paper on "A New Deposit of Slate in Maine," published in this bulletin. In the course of his geologic work in Maine, Professor Dale examined a bed of roofing slate west of the Monson area and well located with regard to new transportation routes. Laboratory tests and careful microscopic work prove that the slate is of fine quality, and it is probable that a new slate district of considerable importance will result from this discovery.

MISCELLANEOUS NONMETALS.

Glass sand.—The glass-making materials of several areas were studied by Survey geologists during the past year, and the present bulletin contains three reports summarizing the principal points brought out by their investigations. Mr. Burchard's paper on the glass sands of the middle Mississippi basin covers an area of particular importance to the glass industry. In the course of this work Mr. Burchard carried out chemical and physical tests, not only of glass sands now in use, but of sands which seemed to be worthy of attention for this purpose. The subject is one of interest, and work on it will be continued during 1906.

Graphite.—A report on the graphite deposits of Maine, by Mr. G. O. Smith, appears in this bulletin. In addition to its geologic and industrial value, this report is notable as containing reference to a new method for obtaining information as to the concentrating possibilities of any given graphite in advance of an actual mill test. Mr. Smith applied microscopic methods, and has determined the sizes to which the products must be reduced before satisfactory separation of the graphite will be possible.

Pyrite.—In connection with his work on the copper deposits of the Appalachian district Mr. Walter Harvey Weed examined a number of pyrite deposits which are likely to prove of value for their sulphur content rather than as copper ores. A report on these deposits will be published later.

Phosphates.—During the last two years interesting developments have occurred in the phosphate industry, discoveries of value having been made in Idaho and Utah. It was impracticable to place Survey geologists in these new districts in 1905, but it is hoped that examinations can be made during 1906.

GOLD AND SILVER.

In addition to the papers here included, which represent the results of recent work by the Survey in important precious-metal mining districts, other reports bearing incidentally on the subject of gold and silver will be found under the head of "Copper," on pages 93 to 145, and "Lead and zinc," on pages 166 to 170.

ORE DEPOSITS OF BEAR CREEK, NEAR SILVERTON, COLO.

By W. H. Emmons.

General description.—The Bear Creek mining camp is in the northeast corner of the Needle Mountains quadrangle, near the head of Bear Creek, a tributary of the Rio Grande near its source. It includes also a group of claims at the extreme head of Elk Creek, to the west just over the continental divide. It is about 17 miles from Silverton; 9 miles of this distance is over a wagon road by way of Howardsville, up Cunningham Gulch, and the remainder is over a good pack trail. The district may also be reached by wagon road from Creede, a distance of about 40 miles, and in the summer of 1905 a trail was being constructed from Elk Park, on the Denver and Rio Grande Railroad, only about 9 miles away. The country is extremely rugged and much of it is above timber line. The region was prospected as early as 1878. The Gold Bug mine was among the first located and was sold to Kansas City parties, who, it is said, took out about $50,000 worth of very rich ore. The Good Hope and Sylvanite have also produced considerable amounts, and shipments have been made from a number of other properties. The entire district has produced about $200,000, chiefly in high-grade tellurium ores. Nearly all of this was packed out by mule trains.

When the camp was visited in August, 1905, the most largely developed mines had been idle for years and the portals of several of their tunnels were blocked with snow and ice, so that entrance to all the workings was impossible. A number of smaller properties were being developed, and the data gained from the examination of these and from the surface workings of the larger mines appear to be in full accord with those reported for the workings then inaccessible.

Geology.—The geology of the Needle Mountains quadrangle is treated in folio 131 of the United States Geological Survey, by Whitman Cross and Ernest Howe, and their geological map was used as a basis for this report.

The Bear Creek deposits are located in an area of pre-Cambrian schists, slates, and quartzites, partly covered by San Juan andesite tuffs and by later flows. The Archean schists, which are the oldest rocks, have a laminated, streaked appearance and are composed mainly of mica, quartz, and feldspar. Seams or veins of quartz, often as much as 3 or 4 inches wide, are common. These are known to prospectors as "bull quartz" or "barren quartz," and are carefully avoided.

The slates and the quartzites belong to the Uncompahgre formation and, though pre-Cambrian, are younger than the Archean schists, upon which they rest unconformably. They are the metamorphosed products of shale and sandstone. Certain portions of the shale were sandy and after metamorphism resulted in a hard, dense, and easily fractured rock, much like the quartzite.

The pre-Cambrian rocks are rather closely folded, the axes of the folds trending generally a few degrees south of east. They are also faulted, the faults running nearly east and west, approximately with the strike of the beds. The andesite tuffs and flows rest upon a very irregular eroded surface of the pre-Cambrian rock. They have suffered little change since their deposition.

A long, narrow fault block of the Uncompahgre quartzite enters the area just south of Beartown and extends nearly due west to the head of Elk Creek. On the north it is in faulted contact with the Archean schist and on the south with other Uncompahgre schist and quartzite. It is partially covered by the Tertiary volcanics. Where it is the surface rock it stands up conspicuously above the surrounding country and is very generally mistaken for a dike, which form is strongly suggested by its long, narrow, regular outline. A number of claims are located along this fault block, among which are the Good Hope, the New York and Brooklyn, and the Silverton. The lodes cross this fault block nearly at right angles to the faults. They are more conspicuous in the quartzite than in the surrounding slate and schists.

Ore minerals.—The ore deposits are narrow fissure veins composed chiefly of white quartz, in which are scattered small masses or pockets of gray ore minerals. While quartz is by far the most important gangue mineral, calcite, barite, and a soft white material, probably kaolinite, are also present. The metallic minerals are a telluride of gold and silver (probably petzite), tetrahedrite (or gray copper), iron pyrite, marcasite (or white iron pyrite), copper pyrites, bornite (or peacock ore), galena, sphalerite, arsenopyrite, limonite, hematite, malachite, and azurite. None of these minerals have been discovered in sufficient quantities to be of economic importance except the telluride and the gray copper. These occur very intimately associated. What appears to be a single mineral from the Good Hope mine gave tests for tellurium, copper, arsenic, antimony, and sulphur. This mineral has the physical properties of gray copper. The tellurium mineral probably occurs also in a much purer state, since roasted specimens which have been taken from the Good Hope mine show light-yellow globules of considerable size sticking to the white-quartz gangue.

White iron pyrite is found in relative abundance, especially at the Sylvanite and Kankakee properties. Its occurrence is similar to that of the ore minerals and it has been mistaken for a telluride. It may be distinguished from the tellurium ores by the darker color of its powder, its greater hardness, and its tendency to assume botryoidal or roundish form.[a]

Pyrite and chalcopyrite (copper pyrites) occur as small masses and crystals in the gangue and to a certain extent in the country rock. Assays of these minerals show that they carry very low values in gold and silver. The copper, lead, and zinc minerals have not been found in sufficient quantities for profitable exploitation.

Ore deposits.—Some of the veins are well defined and their decomposed outcrops marked by yellow iron stains may be followed along the surface almost continuously for several hundred feet. Their usual trend is nearly north and south. Those of an important group run about S. 7° W. The veins are usually vertical or are inclined less than 10° from that position. The fissures do not appear to be closely related to the larger structural features of the country, but cut the faults, the axes of the folds, and the fissility of the rocks at a high angle. The fissures cut all the rocks, but are most clearly defined in the quartzite or in the siliceous portion of the slate. These rocks are strong and brittle, and are better adapted to forming and holding open the cavities in which the quartz and ore may be deposited than are the slates. Along the outcrops of the Gold Bug lead there are a number of shallow surface workings. Some of them are said to have produced several hundred dollars' worth of ore. They are all in hard, rather siliceous phases of the slate, and it is reported that in the development of the Gold Bug mine the profitable ore pockets were found in siliceous walls.

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[a] Test for tellurium: Take a piece of the mineral about the size of a 0.22 ball, crush to fine powder, place in a glass vessel and pour in about as much concentrated sulphuric acid as would fill an ordinary thimble. Heat gently. If tellurium is present, the solution will assume a reddish-violet color.

The veins vary in width from the thickness of a knife blade to 2 or 3 feet, and the Gold Bug vein is said to reach a maximum of 6 feet. While they usually have pretty well-defined limits, there is often a considerable amount of the country rock contained in the vein matter, so that in certain cases where the country rock is cut by quartz stringers it is impossible to determine the wall definitely. For considerable distances the veins may be entirely barren of the precious metals, while at the end of this barren streak a rich pocket sometimes occurs in which are large quantities of high-grade ore. When this pocket has been removed another barren streak is apt to be encountered. This erratic distribution of the ore has had a tendency to discourage continued effort at exploitation, and while a considerable amount of development work has been done the principal mines are at present idle.

Summary.—At Bear Creek, Needle Mountains, Colorado, gold and silver telluride, gray copper, and other minerals occur as pockets and stringers in quartz veins which cut the Uncompahgre quartzites and shales and older pre-Cambrian formations. These veins appear to have no intimate relation to the folding, faulting, or schistosity of the rocks. They are most clearly defined in the quartzite or in the more silicified portions of the shale.

THE HAHNS PEAK GOLD FIELD, COLORADO.

By Hoyt S. Gale.

LOCATION.

Hahns Peak is situated in northwestern Colorado, about 15 miles west of the Park Range, which is here the continental divide. As it stands apart from the main range, its sharp, white cone is a conspicuous landmark from a large part of Routt County. It was occupied as a triangulation station by the United States Geological Survey in 1901, and its elevation was then determined as 10,862 feet, which is 44 feet less than the barometrical measurement by the Fortieth Parallel Survey in 1872. At the very foot of the mountain is situated the little town of Hahns Peak, the county seat of Routt County. Several towns of this county along Yampa River have now far outgrown it in size and commercial importance. It is reached from Rawlins, Wyo., on the Union Pacific Railroad, to the north, distant about 110 miles by stage road; and from Wolcott, Colo., on the Denver and Rio Grande Railroad, to the south, also about 110 miles by stage road. Travel is mainly by way of Wolcott.

The peak and the broad stretches of park land that lie about its base have long been known as a gold camp. Its placers are reported to have been discovered in 1865. Eight or ten years ago, with the working out of the richer gravels, prospecting was begun higher up on the mountain slopes in search of the original veins. This search, however, has not met with much success.

FIELD WORK.

During the first week of October, 1905, an opportunity was afforded to the writer to make a hasty examination of this district, the results of which are chiefly expressed in the topographic and geologic maps that accompany this report. Had time permitted, the work might properly have been extended to include Little Red Park, Big Red Park, and the neighboring ridges within a few miles' radius north of the peak, and also a larger area in and about the park land to the south. Prospecting has shown the gravels of these parks to be gold bearing. The geologic structure of the region is more complicated than is expressed on the map (Pl. I), but enough is shown to indicate the general problems involved.[a]

This region was visited in 1872 by S. F. Emmons, then of the Fortieth Parallel Survey, and a general description of the area and its rocks is given in the King report.[b] Since this first report mention has been made of this district in a few publications.[c]

GEOLOGY.

ROCK FORMATIONS.

General description.—The main mass of the Park Range, which is part of the Rocky Mountains, is a vast complex of granitic rocks, gneisses, and schists, which have been hitherto referred to the Archean. West of the Park Range lies the Colorado Plateau, made

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[a] The writer wishes to make acknowledgment to Messrs. Charles Blackburn and Thomas A. Brown for the courtesies and assistance which they extended to him in the field.

[b] King, Clarence, Geological Exploration of the Fortieth Parallel, vol. 2, 1877, pp. 173 et seq.

[c] Parsons, H. F., and Liddell, Chas. A., The coal and mineral resources of Routt County: Colorado School of Mines, Bull. 1, vol. 1, 1903. Draper, Marshall, Hahns Peak: The Colliery Engineer, May, 1897.

up largely of sediments of Mesozoic and later periods. These sedimentary rocks are sharply tilted, folded, and broken along the immediate flanks of the older mountain mass and extend away to the west in gentler folds until they dip beneath the mantle of less consolidated Tertiary sediments.

Hahns Peak and the Elkhead Mountains are uplifts of recent intrusives which break through the sedimentary rocks of the eastern portion of the Colorado Plateau. The region of these later uplifts is one of marked diversity of features. The rugged peaks and ridges of igneous formation are interspersed with patches of the plateau topography and structure (see Pl. II).

The rock formations about Hahns Peak are similar to those found along the eastern base of the Rocky Mountains.

ARCHEAN.

The oldest are the Archean gneisses, schists, and granitic rocks already referred to. The rocks of Farwell Mountain belong to this general series. They consist of gneisses, schists, diorites, coarse red granite, pegmatites, and other rocks. They are largely, if not wholly, igneous, although some of the schists may represent ancient and much altered sediments. Their general distribution only is indicated on the map.

RECENT IGNEOUS ROCKS.

More recent igneous rocks of at least two distinct types, rhyolitic and basaltic, are present. One of these, locally known as the "white porphyry," forms the core of Hahns Peak. This rock is light colored, usually more or less coarsely porphyritic, showing much quartz in distinct rounded masses, and often phenocrysts of orthoclase feldspar. In the outlying dikes these feldspar crystals are often large and very perfectly formed. The groundmass varies in color from white to pink and gray. Thin sections have been prepared from specimens of this rock collected from the summit of the peak, from the wall rock of the Southern Cross tunnel, and from the smaller knobs south of the main peak. These slides were examined by Mr. Albert Johannsen, who gives the following petrographic description. Under the microscope the slides show phenocrysts somewhat less in amount than the groundmass. The phenocrysts consist of quartz and orthoclase about equal in amount, plagioclase in less amount than either of the foregoing, and a still smaller quantity of biotite mica. The groundmass is apparently a devitrified glass of feldspar-quartz aggregate with numerous biotite shreds. Both phenocrysts and groundmass are considerably altered. The rock is classified as a rhyolite-porphyry containing considerable plagioclase.

The mass composing Hahns Peak seems to have been thrust up from below, in places lifting and arching the Cretaceous rocks and in other places cutting through the formations (see fig. 1). The main summit has the topographic outline of a volcanic peak, but this summit is only a small part of a huge mass of rhyolitic material of fairly uniform composition. The irregular surface of this intrusive mass is exposed on several minor peaks on various sides of Hahns Peak, and many dikes of the same material radiate into the surrounding sediments. These dikes cut through instead of arching the sediments.

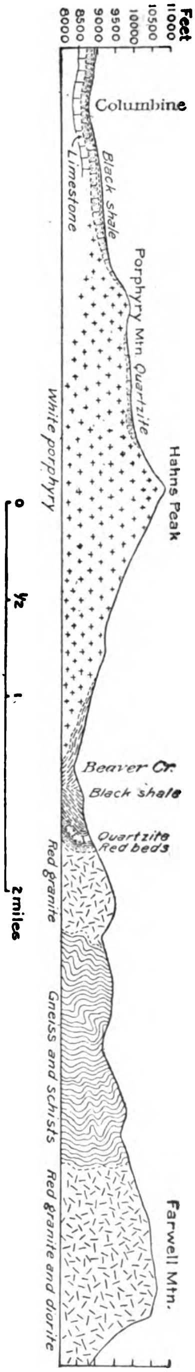

FIG. 1.—Cross section through Hahns Peak and Farwell Mountain.

The structure that this peak suggests is that of a laccolite—a lenticular body of igneous rock intruded into the bedding planes of a sedimentary series. Its formation is explained as the result of an ascending stream of molten rock, which expands laterally before reaching the surface and, by lifting the overlying beds, accumulates in a great mass in the chamber so made. Subsequent erosion of the overlying sediments may expose various portions of its irregular surface. That the Hahns Peak mass is of a lenticular character is no more than supposition as a probable explanation of its relations to the surrounding sediments, for no direct evidence as to the character of the base of this mass was observed.

The second intrusive is a typical olivine basalt.[a] It is shown in a prominent dike north of Hahns Peak between Columbine and Little Red Park. This rock forms a large part of the Elkhead Mountains to the west and southwest of Hahns Peak. Both of these intrusives cut through Cretaceous rocks and are therefore of later age. By analogy with similar occurrences elsewhere they are probably of Tertiary age.

SEDIMENTARY ROCKS.

Red Beds.—The oldest of the sedimentary series here shown are the "Red Beds" of probable Triassic age. They are composed of red sandstone, red shale, and conglomerates with well-rounded pebbles of granitic material, such as make up this formation in many parts of the West. The one undoubted exposure of these beds in this field is in normal position, lying next the Archean rocks at the western foot of Farwell Mountain. On the road between Hahns Peak post-office and Columbine are some exposures of variegated shaly soil and some prospect pits in material that strongly suggests the Jurassic formation, but these are not represented on the map.

Loosely cemented, very coarse conglomerates of rounded pebbles of granitic rocks are also shown in several places. These have likewise been omitted from the map on account of uncertainty as to their extent and proper classification. They were found high on the mountain slopes and in the ravines in the vicinity of the white porphyry. Whether they belong with the "Red Beds" at the base of the sedimentary series or are scattered patches of overlying and considerably later Tertiary beds could not be determined. If they do belong to the "Red Beds" series, it seems strange that they should have been so little altered by their proximity to the intrusive rock of Hahns Peak, for the Dakota quartzite above the "Red Beds" has been very completely vitrified.

Dakota formation.—The next formation showing in outcrop is the Dakota quartzite and conglomerate. It is composed of beds of conglomerate, characterized by perfectly rounded pebbles of exceedingly hard material, of white and gray quartz and a darker flint. Its upper portion is white, even-grained sandstone and quartzite. Its unusually complete silicification in most parts of this field is attributed to the effect of the intrusion of the Hahns Peak porphyry. It lies nearly flat over a considerable area about Columbine, rising on the north and west flanks of the peak to within a few hundred feet of the summit. In scattered patches it also shows at many other places throughout the field. The shaft known as the "Minnie D," just north of Columbine, was put down through this formation where it is nearly horizontal and should give a good measure of its thickness. This shaft passed through the Dakota into a compact blue limestone below, which is probably the Jurassic limestone, found elsewhere immediately below the Cretaceous. A record of the measurements in this shaft is given later under a description of this property.

Benton shale.—Many of the shafts about Columbine pass through a considerable thickness of black shale before striking the Dakota quartzite. This shale is similar in character and position to that called Benton east of the mountains. Where not baked by igneous contact, it is soft and very dark, with calcareous seams. Shells of oysters and *Inoceramus* were found in these calcareous seams. The upper valley of Beaver Creek seems to have been opened out on a narrow syncline of these shales, lying between Farwell Mountain and

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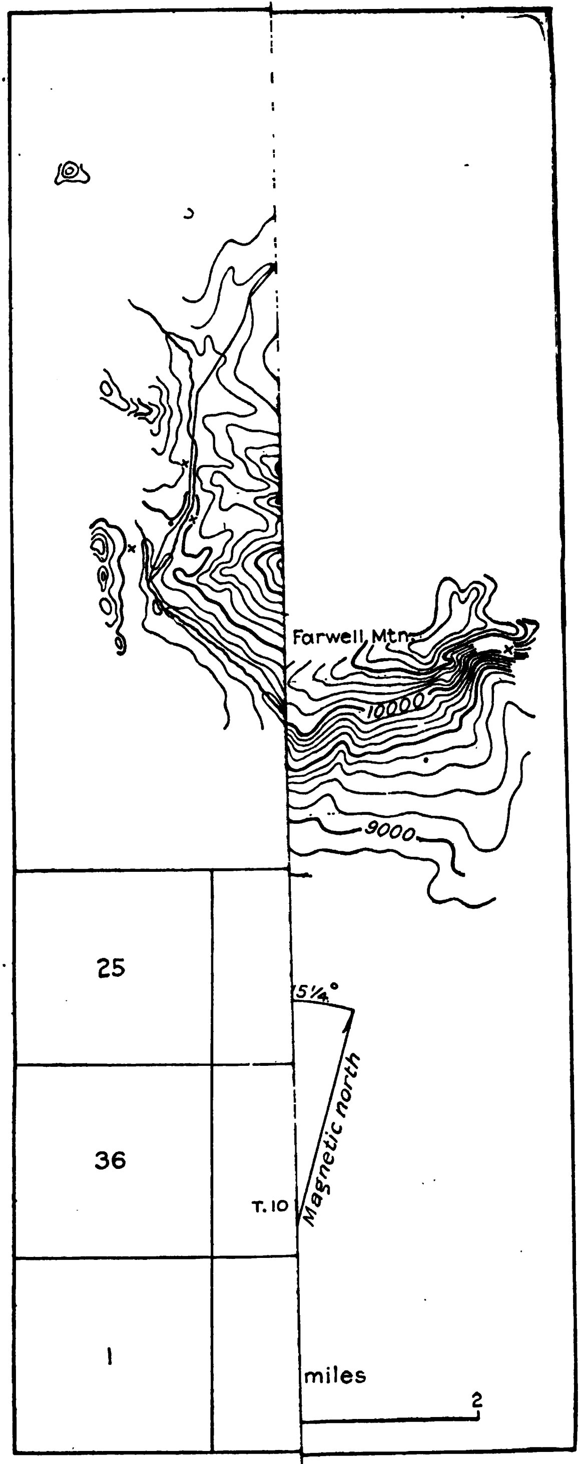
[a] Thin sections of this rock were also examined by Mr. Albert Johannsen.


Farwell Mtn.
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the uplift of the Hahns Peak porphyry. Similar shales show at many other parts of the field, and wherever exposed over a considerable area they take the form of an open flat or park. It is probable that the large parks now buried in rock débris have been eroded on areas of these soft black shales. Above the black shales, but not showing within the field of this report, are light-colored sandstones and shales, 2,000 to 3,000 feet thick, carrying many coal seams.

Recent gravels.—These deposits are in two forms, the "bars" and the stream gravels. The bars are original alluvial fans, partly cut away by recent erosion. The remaining portions of these fans stand above the present stream grades to a height of perhaps 50 feet. Their position at the mouths of narrow gulches along the margins of the parks is evidence that they were built up of the rock débris washed from the mountain slopes. The stream beds in the open parks are bowlder and gravel filled, in some cases to a considerable depth below water level. Practically all of the park land in this vicinity is buried in bowlder and gravel deposits, all of which seem to be more or less gold bearing.

DEVELOPMENT.

THE PLACERS.

On the south side of Hahns Peak the bars have been worked in two places. A considerable pit has been left by the washing on the bar immediately west of Ways Gulch, but no report was obtained of the results of this work. The most extensive workings in the field have been those of Poverty Bar. On a lower portion of these deposits the town of Hahns Peak itself is located. Here the gravels stand some 40 to 60 feet above the present stream grade. A large proportion, variously estimated at from 75 to 90 per cent, of this material is composed of rounded bowlders and pebbles of the white porphyry, vesicular in appearance, the cavities being probably those left by weathering out of the feldspar phenocrysts. Besides the white porphyry are pebbles of vein quartz, quartzite, conglomerate, black shale, and slate, and some pebbles of granite, both angular and rounded, the whole very slightly agglomerated. The gravels are covered by a thin layer of soil. All of this rests upon a bed rock of stiff sandy clay, very uniform in character and similar to the bed rock found throughout the field.

Water for hydraulicking has been brought in a long ditch (about 27 miles) from a headwater tributary of Elk River to the east of Farwell Mountain. A large proportion of this bar has been worked over, but it is claimed that there is as much good ground left as has been washed. It is said that $84,000 was taken from it in one summer.

The earliest and richest of the workings were in the stream-level gravels of Ways Gulch at the western foot of Grouse Mountain. These were worked over with shovel and sluice box, and are reported to have yielded large returns. The stream bed was narrow, however, and the gravels there have long since been worked out. A test pan taken from these tailings showed several coarse colors.

The lower courses of these streams have been thoroughly prospected and the gravels have very uniformly shown values. That these values were not sufficient to repay working by hand is evident from the fact that these claims have never been worked. After leaving the bars the streams come down to such light grades that much difficulty would be encountered in the disposal of the tailings. Where these streams leave the park (about at the southern edge of the area shown in the topographic map), they again fall off more rapidly, and would here afford a dump. Some of the placer claims now held on this lower ground are represented on the geologic map, to indicate roughly the extent of these low gravels.

The question of the origin of the Hahns Peak gold is by no means solved. In character it is in large part moderately coarse flake gold, and is alloyed with silver to such an extent that it sells for about $13 an ounce. Many very small nuggets are found inclosed in vein quartz. Away from the mountain slopes, in the open bottoms, the gold is said to be slightly purer. It is possible that the gold of the placers is a reconcentration from the loosely consolidated conglomerate already described under "Red Beds." The Archean material, of which this conglomerate seems to be wholly composed, is commonly the original seat of gold-quartz veins. The wearing down of such granitic material is a common means by which such veins are worked over and concentrated in nature. The conglomerate beds may be the base of the Hahns Peak laccolite. Gold once transported with these pebbles from an older mountain mass may have been later resorted and concentrated on the slopes of Hahns Peak.

Reports of assays of the Hahns Peak Porphyry claim a very uniform content in gold, of from 30 to 50 cents per ton throughout this rock. This indicates the possibility that the porphyry may be the source of the metal in the placers. A number of tunnels have been driven into the peak itself in search of the original gold veins. Most of this work has now been abandoned. As the gold in the porphyry is in such a finely divided state and as no nuggets or gold-quartz seams have ever been discovered there, the weight of this negative evidence lies against the theory that the gold was derived from the porphyry. On the other hand, the most productive of the placer grounds lie in such position that their material has been derived from the slopes of the porphyry peaks. Seventy-five to ninety per cent of the pebbles in the gravels are of the white porphyry itself. It is probable, therefore, that the gold has been in considerable part derived from the Hahns Peak porphyry. Although the occurrence of the coarser gold has not been discovered within the mass of the porphyry itself, it may have been deposited at the time of eruptive activity in and about what was then the contact of these igneous and sedimentary rocks. Later erosion and the present mantle of slide rock may have obscured this zone.

VEIN DEPOSITS.

In this field two lode properties have shipped ore to the smelter—namely, the Tom Thumb and the Minnie D. Both have been idle for a number of years. The Tom Thumb was not visited, and inspection of the Minnie D. was limited to an examination of the dump. The Tom Thumb is situated on the west side of Hahns Peak, near the summit. The ore as shipped from the Tom Thumb is a galena, much of which is altered to a sand carbonate. As reported, it occurs along a zone of brecciation within the Hahns Peak porphyry. Seen from below, the mine has the aspect of a tunnel driven in on the shearing zone of a huge landslip. This has the corroborative evidence that the tunnel is reported to run in nearly parallel to the mountain face. Assays from a representative shipment of about 18,000 pounds gave 52 ounces of silver, 2 ounces of gold, and 51.8 per cent of lead per ton. The mine is reported to have shipped 200 tons of ore, in part to Denver by wagon and in part to Leadville The Minnie D. is situated near Columbine, in an elevated flat of approximately horizontal rocks. It was opened by a vertical shaft 325 feet deep. The record of strata passed through, as furnished by Mr. Daniel Stukey, of Steamboat Springs, Colo., is as follows:

Section at Minnie D. mine, near Columbine, Colo.

	Feet.
Black shale	25
Quartzite	42
Shale	80
Quartzite and conglomerate	35
Limestone and dolomite	140+

All these rocks were found in the dump. It is probable that they represent the Benton and Dakota of the Cretaceous and the Jurassic limestone. The ore was not seen, but $1,500 worth is reported to have been shipped to Leadville, smelter returns giving 0.42 ounce gold and 8.32 ounces silver per ton. At the time of visit the works had been abandoned for several years.

The Southern Cross tunnel lies on the south side of the peak, about 1,000 feet below the summit.

This passes through the following strata:

Section at Southern Cross tunnel, Hahns Peak, Colorado.

	Feet.
Porphyry talus slope	75
Solid white porphyry	50
Light-colored plastic kaolin clay	125
An apparent fault breccia, ending in a black clay shale	28
Solid white porphyry	322
	600

Mr. Richard Paulson is still at work on this tunnel. This development is important as showing that zones of solfataric action exist within the mass of white porphyry. Some mineralization has taken place along the breccia zone, and a few little streaks of galena and silver have been found. The plastic kaolin clay is interpreted as the product of decomposition in place of the white porphyry, and the breccia of angular fragmen s as marking a zone of faulting. The porphyry beyond the breccia to the breast of the tunnel is considerably altered, as evidenced by the kaolinization of the feldspars.

The Oro-Cache tunnel is on the east side of the peak. It is said to have been driven 600 feet into the white porphyry in search of the gold veins. It is now abandoned and inaccessible.

The Ely-Young tunnel, on the west side of the peak, passed through a porphyry talus slope for about 150 feet, then through the black shale of the Benton to the Dakota quartzite, about 400 feet in all, in the expectation of finding ore between these rocks. At the time of visit the tunnel had passed into the quartzite, but no mineral had been found.

On Farwell Mountain is a group of prospects entirely distinct from those that have been described from the rest of this field. About thirty claims are located here, on most of which assessment work only has been done. A few of the developments have been carried in from 100 to 200 feet. The ore indications seen were of copper, mostly impregnations of a coarse granite and pegmatite, and of horneblende-gneiss and diorite, usually near the contact of these two groups of rocks. There are also quartz veins carrying mineral, but such as were seen were in the form of stringers, with no evidence as yet of strong fracture zones. The minerals were mainly the alteration products malachite and azurite, with some chalcopyrite, and possibly bornite and chalcocite. These are said to have assayed values in gold and silver. No workable ore bodies have yet been discovered.[a]

CONCLUSION.

Interest in this field is revived with the expected advent of the Denver, Northwestern and Pacific Railroad. Nearer railroad facilities may render feasible projects which are not so under present conditions. In the placer grounds the deposits that would pay under the methods of washing hitherto employed are mostly worked out, but they may yet be worked to a profit by hydraulicking or by dredging. The difficulty in hydraulicking in a great part of the field is the lack of grade for the disposal of tailings. Dredging has not yet been tried, though the position of the gravels, the softness of the bed rock, and an ample water supply are all favorable to this method of treatment.

With regard to the lode prospects the work already done shows that there has been mineralization within the mass of the porphyry of Hahns Peak, but as yet the character of the deposits, whether simple impregnation of the country rock or actual lode deposits, has not been satisfactorily determined. Ore is also said to have been found in the Minnie D., following bedding planes in the sedimentary beds surrounding the porphyry body, but such indications do not offer much hope for permanent deposits unless they should be found in the underlying limestone. This limestone, however, was not found at the surface.

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[a] For a more complete description of the deposits and associated country rocks of similar character, see Spencer, A. C., The copper deposits of the Encampment district, Wyoming: Prof. Paper U. S. Geol Survey No. 25, 1904.

As a general rule it may be said that it seems inadvisable to drive long tunnels or sink shafts in barren rock, as has been done in some cases, in the remote hope of striking an ore body. Only actual indications of ore should be followed by such explorations until the existence of workable bodies has been proved by workings sufficiently extensive to permit the determination of the geologic character of the deposits that may exist here.

For the deposits in the Archean, where the probable values lie in the copper ore, it must be borne in mind that these ores make a disproportionately large showing at the surface. Until the existence of strong vein deposits has been actually proved by sinking on the outcrop, it is inadvisable to drive crosscut tunnels to cut a lode in depth which shows, as do most of the prospects, only little stringers and impregnations of the country rock at the surface.

THE IDAHO SPRINGS MINING DISTRICT, COLORADO.

By J. E. Spurr and George H. Garrey.

INTRODUCTION.

A preliminary report on the geology and ore deposits of the Georgetown quadrangle, based upon work done in the vicinity of the towns of Georgetown, Silver Plume, and Empire, appeared in 1905.[a] Last summer (1905) Mr. Spurr spent ten days and Mr. Garrey was engaged for six weeks in studying mines south and west of Idaho Springs—that is, in the northeastern, previously unstudied portion of the Georgetown quadrangle. The following brief report presents the main results of this second season's work.

Idaho Springs, which is on a branch of the Colorado and Southern Railroad, lies about 40 miles due west of Denver, in the valley of Clear Creek, near the junction with Chicago Creek. It is the largest town in Clear Creek County and has a population of about 2,500.[b] There are at least 12 concentrating mills operating at Idaho Springs, which is the milling center for the district.

TOPOGRAPHY.

Idaho Springs has an elevation of about 7,525 feet[c] above sea level. From this altitude in Clear Creek Valley the mountains rise by gentle slopes to elevations as great as 11,000 feet a few miles distant. In their rounded forms, however, the mountains here contrast strikingly with the rugged peaks near Silver Plume and Georgetown.

The topographic map of the Georgetown quadrangle on the scale of 1 mile to the inch, made by Frank Tweedy during the summer of 1903, is now in print.[d] This map and the Idaho Springs special map, on a scale of 1,000 feet to the inch, made by Pearson Chapman during the summer of 1904, were used as a basis for the geological work.

GEOLOGY.

General description.—The rocks near Idaho Springs are almost identical with those in the vicinity of Georgetown. The oldest formations of the Rocky Mountains, presumably pre-Cambrian, form a "complex" comprising the main mass of the mountains. These rocks include schists, gneisses, basic igneous rocks of the nature of hornblendites and diorites, granites, and pegmatites.

All these rocks are cut by later intrusive bodies of porphyry.[e] The dikes of porphyry, which vary considerably in color and texture, often contain angular fragments of the wall rocks and of fine-grained contact phases of the porphyry itself. They are much more numerous in this part of the quadrangle than in the vicinity of Georgetown and Silver Plume. That the porphyry as a rule is earlier than the veins is shown by the fact that the veins pass in some cases from granite or gneiss into and through a porphyry dike and continue uninterrupted into granite or gneiss on the other side.

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[a] Spurr, J. E., and Garrey, G. H., Preliminary report on the ore deposits in the Georgetown, Colo., mining district: Bull. U. S. Geol. Survey No. 260, 1905, pp. 99–120.

[b] Census report for 1900.

[c] Idaho Springs special topographic map, by Pearson Chapman.

[d] Copies of this map can be obtained from the Director, U. S. Geological Survey, Washington, D. C.

[e] For a fuller description of these rocks, see Bull. U. S. Geol. Survey No. 260, 1905, pp. 101–106.

Placer deposits.—The first discovery of pay gold in Clear Creek County, and one of the first in Colorado, was made by George Jackson about the 1st of April, 1859,[a] on Chicago Creek, just above its junction with Clear Creek.

This is considered by many to have been the first discovery of gold in Colorado, but, according to Hollister, B. F. Langley had, about the end of the preceding January, found placer deposits in a gulch on South Boulder Creek. These deposits, which were known as "Deadwood Diggings," had by the end of March produced considerable gold and were affording employment to quite a number of men. Small amounts of gold had also previously been encountered near Golden, and on Ralston Creek, a small tributary of Clear Creek.

On Clear Creek placer mining was prosecuted from Grass Valley Bar, 3 miles below the mouth of Chicago Creek, to the forks of the South Branch, some 9 miles above this same point.

By the end of May, 1859, there were nearly 300 men employed at "Jackson Diggings" and on the various claims for several miles up and down Clear Creek from this point. These deposits yielded good returns to some of the workers for a great many years; in fact, the yield of the precious metals in Colorado previous to 1864 was almost entirely derived from these placers and from the sluicing of the decomposed surface ores of the veins, for the silver mines were not operated until 1865, and the unaltered gold-bearing sulphides could not be treated with profit. The placers were most profitably worked between the years 1859 and 1863.

The placer gold deposits of Clear Creek County may be classed as (1) river-bar placers, (2) stream placers, and (3) bench placers. The river-bar deposits are those on gravel flats in or adjacent to the beds of the streams. The stream deposits consist of the deposits of bowlders, gravel, and sand filling the channels and forming the beds of the streams. The bench placers are ancient stream deposits which are at present represented by remnants of old stream terraces located at a considerable elevation above the level of the present water courses. There are three conspicuous lines of terraces. While not of glacial origin, the lowest of these, which is about 25 feet above the present stream beds, consists largely of glacial material which has been worked over and transported to its present position by streams subsequent to the period of glaciation. The second gravel terrace, which, according to Mr. S. H. Ball, is possibly pre-Glacial in origin, is found 55 feet above the creek bed. The third set of terraces is 180 feet above the channels of the present streams and consists often of indurated river gravels of late Tertiary or early Pleistocene age.

The principal deposits along Clear Creek occur in the vicinity of Idaho Springs and extend from the junction of Fall River and Clear Creek to the forks, several miles below the town, where North Clear Creek, which flows through Blackhawk, joins the main stream.

"Jackson Diggings," where the first discovery of gold in the county was made by George Jackson in April, 1859, is located on Chicago Creek near its junction with Clear Creek. The exact site where Jackson first found gold is said to be beneath a large willow tree on the road north of Chicago Creek, about halfway between the Jackson and Waltham concentrating mills; this site is now included in what is known as the "Edwards Placer." The material at "Jackson Diggings" consisted of coarse gravel and sand, occurring as bars or flats in or adjacent to the streams, and of deposits forming the stream bed itself. The low benches along the sides and in places on top of the low ridge or spur of land which separates Chicago Creek from Clear Creek just above their union were also worked extensively. Much of this material was sluiced at very large profits in the early days. The deposits of Spanish Bar, which was the name given to the portion of Clear Creek extending from the junction of Fall River and Clear Creek to a point below the Stanley mine, consisted mainly of a mass of bowlders of all sizes, gravel, and sand, filling the channel of the stream, which here runs in a comparatively narrow valley.

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[a] Hollister, The Mines of Colorado, 1867, p. 60.

On the south side of Clear Creek an old river terrace or bench extends from the eastern edge of the Georgetown quadrangle along the south bank of Clear Creek to the western edge of the town of Idaho Springs. This terrace is cut through by both Soda and Chicago creeks and is beveled by Clear Creek. The upper part of the scarp due to the action of the present stream is about 100 feet above the present valley, while the upper part of the terrace, which has a slope making a considerable angle with the present stream, is about 180 feet above Clear Creek.

The terrace gravels, which are now covered by the Arthur and Doherty placer claims, were formerly extensively worked with very profitable results. This terrace, which is located in the southeast angle formed by the union of Soda and Clear creeks, is a bed rock bench of porphyry which in rare instances reaches the surface, but is usually covered with a river deposit averaging 40 feet in thickness. The lower 20 feet of this deposit consists of large rounded bowlders, gravel, and sand, while the upper portion is composed of finer gravels and silts which are capped by talus deposits having an average thickness of 6 feet. The bedding of the materials in these deposits dips at a considerable angle toward Clear Creek.

Good values were found in these deposits, the best ones usually occurring either in the deeper gravel-filled channels or right on bed rock. Where the detritus coating above bed rock was very thick tunnels were run into the stream banks or else shafts were sunk and drift mining was resorted to to expose the gold, which occurred on bed rock in the natural riffles due to the roughness of the old stream bed. Many hundreds of feet of tunneling and drifting on bed rock were run during the period of active development, and according to Fossett[a] there was one tunnel over 900 feet long extending into the bank and hillside adjoining the creek. That the deposits are fairly well consolidated is shown by the fact that untimbered drifts and tunnels run some 40 or 50 years ago can still be explored to a considerable extent.

The high bench found at the junction of Soda and Clear creeks is not visible below this point on the south side of Clear Creek but appears again on the north side about one-fourth mile downstream. At the latter place is a horizontal or slightly sloping shelf or ledge of coarse conglomerate and soft sandstone or granitic arkose of a character somewhat similar to the placer deposits on the other side of the valley. This fairly well-indurated conglomerate, which is comprised chiefly of rounded masses of gneiss and granite but also contains some rounded pebbles of porphyry, is of limited extent and is plastered unconformably upon the rather steep gneiss walls of the valley at this point.

Placer mining remained an important industry in Clear Creek County and added materially to the gold production up to the early eighties. Since that time, however, although considerable work has been done at various times, it has been with variable success and as a rule with little profit. At present, aside from the desultory labors of a few miners who occasionally make fair wages, little work is being done on the deposits.

Hot springs.—On the east side of Soda Creek, about half a mile above its mouth, is a hot spring which has deposited grayish calc-sinter or travertine to a thickness of 4 or 5 feet. The lower several inches of this deposit are soft and heavily iron stained. Similar deposits cover the east bank of Soda Creek for several hundred feet to the north of the present spring. The gravel near the spring is cemented by the same calcareous material and closely resembles the conglomerates previously described. The temperature of the water, as observed in two short tunnels that tap the flow, is 106° and 110° F. According to Mr. J. R. Allison, however, water with a temperature as high as 121° F. was obtained from two wells sunk to a depth of 25 feet below the bed of Soda Creek.

Faulting.—Minor faults are frequent in the mines, but the cross faults rarely displace the veins more than a few feet. The greatest known displacement, that of the Little Mattie vein, where faulted by the "cross vein," is from 10 to 25 feet. In the Newhouse tunnel a small porphyry dike which cuts several pyrite and quartz veinlets is step faulted by a series of parallel faults with offsets of about 6 inches. A pegmatite dike 1 foot in width in the Silver Horn mine is similarly step faulted. As these transverse faults seldom cause difficulties in mining they are of little economic importance except when, as occasionally happens, they are themselves mineralized and their intersections with the main vein produce pay shoots.

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[a] Fossett, Colorado, 1880, p. 381.

Very well-marked and comparatively recent movements have taken place along some of the main veins and in some cases have crushed and mixed the ore with so much triturated rock and gouge that the resulting mass is of little value, although the uncrushed ore streak might have been worked with profit.

MINERALOGICAL CHARACTER OF THE ORES.

The chief gangue minerals accompanying the ores are quartz, siderite, barite, calcite, rhodochrosite, and magnesite. With the exception of quartz, which is the conspicuous gangue mineral of the district, these minerals are found only in rare instances and in small amounts.

The principal ore minerals found in the mines to the south and west of Idaho Springs are pyrite, galena, sphalerite, and chalcopyrite, and they are present in greatly varying proportions. The values are principally in gold, silver, lead, zinc, and copper. The gold, although sometimes free, is usually combined with pyrite and chalcopyrite. In the area to the north of Idaho Springs the ore is mainly cupriferous pyrite and quartz, while to the south and west of the town galena and some sphalerite usually accompany the pyrite and quartz in the gold-bearing ores. As in the ores of the Georgetown-Silver Plume area, the silver generally accompanies galena and sphalerite, and when in quantity is usually associated with tetrahedrite ("gray copper"[a]) polybasite, tennantite, or argentite. The galena is both argentiferous and auriferous, as is also the sphalerite to a much less degree.

In the vicinity of the Lamartine mine, which lies about halfway between Idaho Springs and Georgetown, the ores are chiefly silver bearing, and galena and sphalerite predominate. For example, in the Lamartine mine itself the ratio of silver to gold has averaged 68 to 1 by weight. East and northeast from the Lamartine the proportion of gold increases until some of the mines, which have cupriferous pyrite and quartz veins, such as the Centurion, produce practically no silver.

FORM OF OCCURRENCE OF THE ORE DEPOSITS.

Nearly all the ores occur along fissures which are younger than the porphyry, as well as the older rocks. Most of the prominent veins in the northeastern portion of the quadrangle are parallel to the porphyry dikes, either along the wall or a short distance away from the dike. This close relation of the vein fissures to the dikes may be due to the fact that the contact of the porphyry with the other rocks constituted planes of easy movement, and the intrusion of the dikes may also have made the adjacent rocks more susceptible to fracturing; or the veins may have followed the same planes of weakness, or planes of the same system, along which the porphyry dikes were earlier intruded. In a few cases, however, for example, in the Gomer and Centurion mines, the veins cut transversely across the porphyry dikes. The general trend of the main veins, as well as of the principal porphyry dikes, is from southwest to northeast.

The fact that the ore-bearing zone is coextensive with the belt of porphyry intrusion is significant.

TYPES OF VEINS.

The veins in the vicinity of Idaho Springs may be separated into several types dependent on the grouping of the separate fracture zones. One type consists of a single or several parallel well-defined veins. These usually occur along or near and parallel to the contact of porphyry and the older rocks. Another type has a main or master vein from which smaller veins and veinlets branch. These smaller veins may in turn successively subdivide until they finally die out. There are also special cases of crossing or intersecting veins or lodes.

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[a] The polybasite and tennantite are also called "gray copper" by the miners.

An excellent example of a branching lode is found in the Fraction-Kitty Clyde vein and branches. The first type is well illustrated by the Little Mattie-Newton vein. In the Little Mattie mine there are two porphyry dikes running parallel to one another or else one large porphyry dike which splits into two or more parts, separated by large masses of gneiss and pegmatite. The vein runs approximately parallel to the dikes, at some places entirely in porphyry and at others with pegmatite or gneiss on both walls. Minor veinlets or feeders enter this main vein at long intervals. Moreover, the main vein itself splits up at both ends into several strong but less productive veins, and these become an example of the branching type. The New Era and Great Western veins also run parallel to each other and are only about 75 feet apart. A minor cross vein intersects both of these parallel veins.

The crossing of veins is well illustrated by the intersection of the Black Eagle and Bismark veins.

PAY SHOOTS.

Junctions of two large veins or of branches or feeders with a main vein are frequently sites of ore deposition. Most of the ore in such cases is on the main vein, but some ore is also found along the cross or branch veins for some distance from the junction.

In veins parallel with and at or near the contact of a porphyry dike, pay shoots are sometimes found at the junction of minor branches, but they commonly occur irregularly along the fractured zone. This irregular distribution of the shoots may possibly be accounted for in the following manner. Porphyry or other wall rock, when intensely altered, often changes to a clay-like mass which is soft and tends to close up any fissures running through it. As this clay-like substance is practically impervious to the ore-bearing solutions, these solutions are diverted into the more open channels or spaces between the clayey portions and there deposit the ores. This deposition may be the result of mingling with other solutions or of replacement of the strained or crushed and pulverized rock along the fractured zone.

In the Little Mattie mine crushed pegmatite and gneiss zones are inclosed between two dikes of porphyry. As the dikes converge the "horse" of gneiss and pegmatite is gradually replaced by quartz and ore, until finally the space between the porphyry dikes is filled completely by ore and gangue material, no pegmatite or gneiss being visible. Somewhat similar ore bodies have been formed by the replacement of porphyry instead of pegmatite and gneiss. In such cases the vein, which is entirely in porphyry, splits and incloses a mass of porphyry 2 or 3 feet in diameter. This mass is composed mainly of crushed but comparatively unaltered porphyry; but in places this grades first into porphyry partially replaced by ore and quartz, and then into solid ore and quartz, showing no trace of the original porphyry.

The Little Mattie-Newton vein is crossed by several later and leaner veins. One of these, the so-called "cross vein," faults the Little Mattie vein from 10 to 25 feet. This vein, while carrying only low values itself, seems to bear a definite relation to the ore bodies, for a series of them are found to lie one above another immediately east of the "cross vein." The Chicago-Bismark and the Guy Irving veins likewise intersect the Little Mattie-Newton vein. The first of these, the Bismark, is crossed by the Black Eagle vein and is faulted by it about 6 feet. An ore body was found at this intersection. The Waltham-International and the Amethyst veins are examples of other large veins of comparatively little mineralization which cross the main belt of northeast-southwest veins.

PERSISTENCE OF FAULT MOVEMENTS.

Movements occurring after the solidification of the porphyry dikes caused fissures which contained loose angular fragments of porphyry and the older rocks. Subsequent deposition of ore in these fractures formed a consolidated breccia with the ore minerals constituting the matrix.

Movement has been renewed along the same vein fractures since the ore was deposited and has crushed the vein or the ore breccia just described into a secondary breccia of mixed ore and wall rock, and later solutions have cemented the fragments with silica. Comparatively recent movements have in turn crushed this second breccia and have left the fragments of ore, quartz, and country rock in an unconsolidated matrix of finely crushed and decomposed material. Some of the movements along the veins already referred to have been very pronounced, as is indicated by the well-rounded form and often polished surfaces of the pebble-like fragments filling the vein. Good examples of these friction conglomerates occur in the Stanley and Freeland mines and in the Newhouse tunnel. There is a breccia filling in the Stanley mine, however, which can not be ascribed wholly to movement, but rather to the filling by detritus of a water course along an open fissure.

The later movements also produced the transverse faults already described.

RELATION OF ORE DEPOSITION TO DEPTH.

Ore has been found as deep as 1,800 feet below the surface in the mines south and west of Idaho Springs. Most of the workings, however, reach a depth ranging from 100 to 800 feet.

In many of the mines the vein practically disappears at a variable depth from the surface, only an uncemented fracture or fault zone remaining. It is not, however, fair to ascribe this fact in all cases to direct dependence of the mineralization on proximity to the surface, for a similar decrease and practical disappearance of the mineralization is frequently encountered on following the vein horizontally. The fact is that the ores have been deposited in certain areas, limited in all dimensions, along the fault-zones. Such ore bodies may or may not now be exposed at the surface as a consequence of erosion subsequent to ore deposition. In the majority of cases they probably outcrop, but in some they do not. The Lamartine mine affords an example of an ore shoot that does not extend to the surface. Croppings of the vein gave assays of less than $4 to the ton and no ore was encountered until the ore body was reached at a depth of 100 feet below the surface.

On the whole there is no very striking or complete change in the character of the mineralization within an ore body from top to bottom. In several mines the ore at depths of from 800 to 1,600 feet is as rich as that near the surface.

ECONOMIC FEATURES OF NORTHERN IDAHO AND NORTHWESTERN MONTANA.

By D. F. MacDonald.

INTRODUCTION.

After the detailed study of the Cœur d'Alene mining district by Messrs. Ransome[a] and Calkins in 1903 and 1904, there remained an extent of country stretching a hundred miles to the north, the geology of which was comparatively little known. In order to investigate this field and correlate its rocks with the Cœur d'Alene sediments and the known rocks along the boundary and in northwestern Montana, a geological reconnaissance was ordered. This examination was undertaken by Mr. F. C. Calkins, assisted by the writer, in July, 1905.

A good idea of the location and extent of country covered can be had by following the route taken as it is traced on the accompanying map (fig. 2). Obviously only the main geological features could be observed in passing over so large an area within the time allotted. An endeavor was made, however, to visit mines and prospects wherever possible, although economic investigation was merely incidental.

PHYSICAL FEATURES.

The region investigated is a great succession of mountain peaks and ridges having an average altitude of 5,000 to 6,000 feet. A wide valley forms its western boundary and two large rivers, Clark Fork of the Columbia and the Kootenai, have trisected this extensive mountain region into three northwest-southeast mountain systems. A glance at the accompanying map will show the location of these systems, which are the Cœur d'Alene Mountains on the south, the Cabinet Range in the center, and the Loop Mountains on the north, the latter being subdivided into the Mooyie, Yaak, and Purcell ranges.

The Cabinet Mountains is the only one of the ranges in which rugged saw-tooth ridges, at some points over 8,000 feet high, occur. Here on the north slopes are still found a few small ice fields, remnants of a once extensive system of alpine glaciers.

GEOLOGY.

INTRODUCTORY STATEMENT.

Algonkian rocks prevail over a large area in northern Idaho, northwestern Montana, and southern British Columbia. The best known Algonkian rocks of this particular area are the mineral-bearing formations of the "Cœur d'Alene series," which forms perhaps the major portion of the Algonkian province. Within this area were also found some limy sediments of doubtful age.

Ripple marks and sun cracks show that these rocks were laid down in shallow water. No unconformity was seen throughout the 20,000 feet of their thickness.

Bounding this great Algonkian rock province on the west are Archean schists and gneisses. On the east are the middle Cambrian, Carboniferous, and Upper Cretaceous sediments of western-central Montana. The southern boundary is formed by the extensive body of intrusive rocks of central and southern Idaho. Toward the southwest lie the great lava beds of the Columbia plain.

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[a] Ransome, F. L., Bull. U. S. Geol. Survey No. 260, 1904, pp. 274-303.

The Archean rocks, ancient looking and much metamorphosed, are separated from the later and fresher-looking Algonkian series by a great unconformity.

Younger igneous rocks have cut the sediments of the district as basic dikes and sills, and vast chambers have been stoped out and occupied by intrusions of granite.

In the structure of the district many large normal faults were noted. A few great folds were observed, but in general monoclinal blocks prevail.

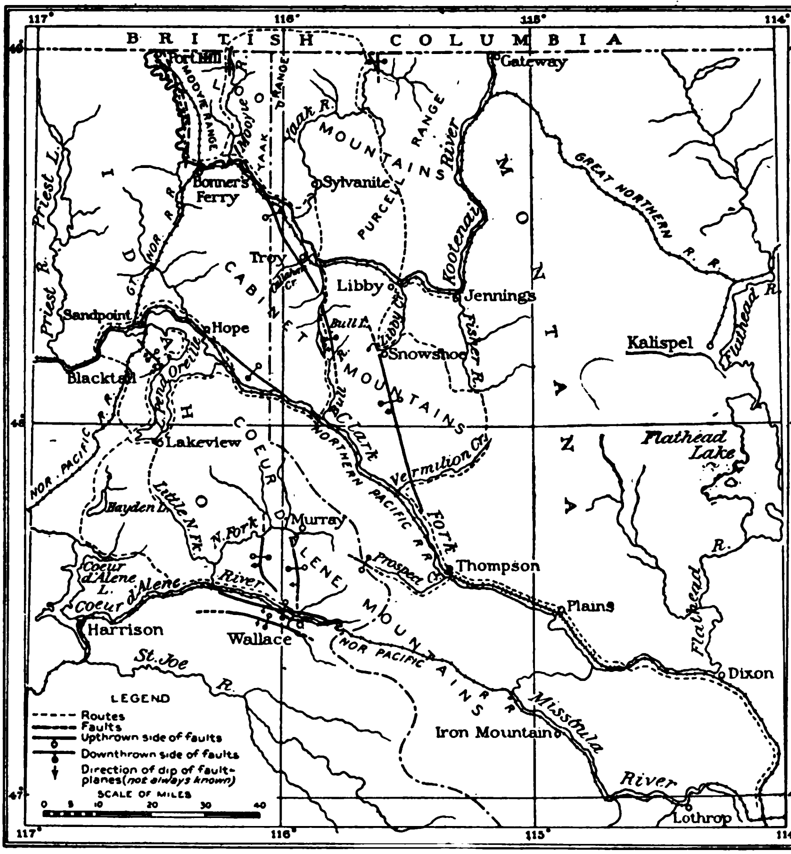

FIG. 2.—Outline map of northern Idaho and northwestern Montana.

STRATIGRAPHY.

ARCHEAN.

The Archean rocks are well shown on the west shore of Cœur d'Alene Lake. Here sediments, now in the form of highly crystallized schists, had been penetrated by numberless dikes and intrusions of granite, later changed to typical gneiss. These intrusions probably took place early in the geological history of the formation and long before extensive metamorphism crystallized the whole into its present form.

ALGONKIAN AND PALEOZOIC.

Cœur d'Alene section.—A good idea of the Algonkian formations of the district can be given by briefly describing the Cœur d'Alene series and using this as a basis of comparison for the other Algonkian rocks.

Tabular section of the Cœur d'Alene series.

No.	Name.	Description.	Approximate thickness.
			Feet.
6	Striped Peak formation	Sandstones, siliceous, generally flaggy to shaly; colors mostly green and purple; characterized by shallow-water features, as ripple marks, sun cracks, etc.	1,000+
5	Wallace formation	Thin-bedded sandy shales, underlain by rapidly alternating thin beds of argillite, calcareous sandstone, impure limestone, and indurated calcareous shale; these underlain in turn by green siliceous argillites. Shallow-water features throughout. Slaty cleavage common.	4,000
4	St. Regis formation	Sandstones, generally flaggy or shaly; usually fine grained and much indurated; colors mostly green and purple; characterized by shallow-water features.	1,000
3	Revett quartzite	White quartzites, generally rather thick bedded; interstratified with subordinate quantities of micaceous sandstone.	1,200
2	Burke formation	Gray, flaggy, fine-grained sandstones and shales, with interbedded purple quartzitic sandstone (the proportion varies widely in different parts of the district) and white quartzite. The formation characterized throughout by shallow-water features.	2,000
1	Prichard slate	Mostly blue-black, blue-gray to light-gray slates, generally distinctly banded. Considerable interbedded gray sandstone. Upper portion characterized by rapid alternations of argillaceous and arenaceous layers, and by shallow-water features. Base not exposed.	8,000+
			17,200

Modifications of Cœur d'Alene section.—Most of the beds forming this section vary greatly toward the north and east; some of them entirely disappear, others grow much thinner, and the remaining ones get somewhat thicker. Moreover, new rocks make their appearance both above and below the Cœur d'Alene series.

The rock which gradually takes the place of the Prichard slate toward the north is a gray, siliceous, fine-grained quartzite which weathers brownish gray. It is well shown north of Sylvanite and has been named Creston quartzite by Daly of the Canadian Survey. Toward the east, however, the Pritchard slate was observed to outcrop throughout the 30 miles between Plains and Dixon.

The Burke formation is essentially the same in composition throughout the district under survey. The Revett quartzite was not observed north of the Kootenai nor east of Missoula River. The St. Regis red and green beds were not well defined north of the Cabinet Mountains. Toward the east they were traced to Iron Mountain, Montana. The Wallace formation is much thicker toward the Cabinet Mountains. Here too, as well as toward the east, it contains a higher percentage of lime. What appeared to be Striped Peak sediments were found at intervals toward the north, but could not be definitely correlated.

Limestone beds of considerable extent occur around the south end of Lake Pend Oreille. They are thought to have been deposited later than the Cœur d'Alene rocks, but were not definitely correlated, as all their observed boundaries were faults or igneous rocks.

Above the Cœur d'Alene series a great thickness of green and gray argillaceous shales, overlain by limy brownish-yellow weathered argillite, has been developed. This is well shown in the Cabinet Mountains north of Bull Lake.

Other limestones occur between Libby and Jennings and on Swamp Creek southeast of Libby. These latter beds are quite pure and are associated with red and green shales. Near Lothrop, on Missoula River, limestone beds were also found, containing traces of what may be crustacean remains. More detailed study may prove these limestones to be of Cambrian or Ordovician age.

IGNEOUS ROCKS.

The igneous rocks of the district fall naturally into two general groups—"granitic rocks;" and basic sills and dikes.

Granitic rocks.—A broad belt of intrusive granitic rock extends along the western boundary of the Algonkian area. Another large intrusion of granite is found just north of Bull Lake in the Cabinet Mountains, and a third great granitic mass outcrops in the basins of Lightning and Callahan creeks. A vast body of very hard, tough porphyritic rock, probably granite-diorite-porphyry, forms a mountain peak on the eastern shore of Lake Pend Oreille.

Basic sills and dikes.—The intrusive sills which sometimes occur in the bedding planes of the sedimentary rocks of the district are well shown at the mouth of Mooyie River and on the boundary 5 miles east of that river. Basic dikes also cut the formations in many directions and in some instances have mineral deposits associated with them.

Basalt.—Several large basalt terraces occur around the south end of Lake Pend Oreille. They are remnants of the great Miocene basalt floods which came in from the south.

QUATERNARY GRAVEL.

The Quaternary gravels are mentioned on account of their economic interest. They form extensive benches high above present river levels. Streams coming in contact with these benches have reworked the material and gradually concentrated the heavier metals in the gravel bars which formed in their channels. A few lean diggings of placer gold have been formed in this way, notably on Mooyie River and Vermilion Creek. Placer mining, however, has not been very productive in the district as a whole.

STRUCTURE.

FAULTS.

A glance at the accompanying map (fig. 2) will show the location and direction of the principal faults better than they can be described. The displacement in some of these normal breaks has been very great, upper beds having been brought into juxtaposition with beds formerly many thousand feet below them. The friction caused by these slips has formed shattered zones on each side of the fissure. Rarely a ridge of quartz-breccia marks a fault. Here the fragments have been cemented by silica-bearing solutions into a mass which successfully resists weathering. Oftener, however, the crushed fragments disintegrate and weather away, marking the break with a V-shaped valley. Oxidizing surface waters percolating freely through these fragments aid the prospector to locate the fault by marking it with an iron capping. These faults have a direct economic importance in that they formed channels of circulation in which the mineral-bearing solutions were able to deposit their loads. Thus were formed most of the present mineral veins of the district. It should be noted, however, that the large faults are not so apt to contain economic deposits as the smaller ones. This may be due to the great area of the large fault fissures and of their brecciated zones, which would render extremely difficult the collection by percolating waters of enough mineral to make an ore deposit. The Snowshoe fault is no exception to this, because, though very large, it is clearly cut and has no brecciated zone; hence the portion subject to mineralization is quite restricted.

MINERAL RESOURCES.

General statement.—To the northwest of the region under survey are the great mineral districts of Slocan, Arrow Lake, Lardeau, and Revelstoke, in southern British Columbia. To the southeast are the famous Cœur d'Alene silver-lead mines. Indeed, a fairly complete series of mineralized areas may be traced between these two mining districts. This connecting mineral zone may be observed on the northeast slope of the Cœur d'Alene Mountains at Prospect Creek. It continues across into the Cabinet Range at the heads of Fisher River and Vermilion, Libby, and Callahan creeks, and so northward into the Loop Mountains at Sylvanite. The Pend Oreille mineral area may be said to mark its western flank.

At different periods many small mining camps have flourished in this general region. Much development work has been done, but at present only one property is making regular shipments. Sufficient low-grade ore has been opened on several claims to encourage further work.

CHARACTER OF DEPOSITS.

Nearly all the metalliferous deposits observed in the region are veins which have been formed by filling fissures and replacing their walls. In some instances after the vein was filled movement again took place which slickensided the vein material. There are a few contact deposits of minor importance.

It may be noted that the base ore lies comparatively close to the surface in this region, and there is very little secondary enrichment or concentration of the leached-out surface values at depth. This may be accounted for by the rapid erosion which the surface rocks have undergone, particularly where glaciation has prevailed.

The only noteworthy nonmetalliferous mineral resources are some limestone beds from which lime is being manufactured.

DESCRIPTION OF DISTRICTS.

For convenience the economic deposits will be described by districts in the following order: Pine Creek, Lake Pend Oreille, Troy, Sylvanite, Snowshoe, Cabinet, and Prospect Creek.

PINE CREEK.

General features.—Pine Creek is about 6 miles west of the Bunker Hill and Sullivan and the Last Chance mines. It flows in a northerly direction into Cœur d'Alene River and drains a large wooded basin.

The country rock is Prichard slate and the veins are fissures which have generally been formed by faulting and which often have their walls partly replaced by vein material. The vein filling is white quartz and crushed country rock, the whole somewhat iron stained. The ore is a silver-bearing galena associated with zinc and some siderite and pyrite. The silver-lead values are low, and transportation charges are so high at present that mining for zinc, though the ore sometimes runs up to 20 or 30 per cent, is not profitable. The weathered zone of these veins was fairly rich in silver and lead carbonates to a slight depth, but the base ore was soon reached and development work was then usually suspended. Although much exploration work had been done in the district and considerable bodies of low-grade silver-lead-zinc ore found, very little mining activity was evident at the time of visit.

Mines and properties.—The Anderson group, 3 miles from the mouth of Pine Creek, has a few tons of rich-looking ore on the dump. A 60-foot adit and 20-foot winze are the extent of development work.

At the King property, a mile south of the Anderson property, a few tons of ore have been extracted from an 85-foot adit.

The Douglas, 6 miles south of the King, has had a considerable amount of development work done. Three hundred tons of ore are on the dump and about 10,000 tons in sight. The ore is peculiar in that it seems to be a fine-grained galena, carrying, it is reported, almost 30 per cent of zinc.

The Surprise, on another branch of Pine Creek, is about 2 miles southeast of the Douglas. A 450-foot crosscut adit taps the vein at considerable depth. It is said to give an average assay of 31 per cent lead, 30 per cent zinc, and 10 ounces of silver to the ton.

The Nevada Stuart is just across the creek from the Surprise, and is on the same northwest-southeast lead. A 300-foot adit constitutes the development work.

The Highland Chief, half a mile up the creek from the Nevada Stuart, has been the scene of considerable development work. It was reported that its past period of idleness had recently been broken by a shipment of two carloads of ore.

The Nabob, on Stone Creek, a tributary of Pine Creek, expected to ship four carloads of ore shortly.

Outlook for the district.—The mining future of Pine Creek depends on the discovery of some satisfactory treatment for saving and separating the silver, lead, and zinc values of the ores. Such treatment should enable the district to become an important producer, but under present conditions development on a large scale can hardly be expected from it as a whole. It is possible, however, that ore bodies may be uncovered which contain a minimum of zinc and sufficient silver and lead to become dividend payers even with present methods.

LAKE PEND OREILLE DISTRICT.

LAKEVIEW.

General features.—At the southeast end of Lake Pend Oreille, on a bench just in front of a high mountain, stands the little town of Lakeview. Although extremely quiet now it once gave promise of being a most active mining center.

In October, 1888, Messrs. Frederic A. Webber and S. P. Donnely came across from Eagle Creek, in the Cœur d'Alenes, on a prospecting trip. They made a discovery, located on it, and went back for supplies. They kept their secret well, but a suspicion of their find got abroad. On their return an eager throng followed them back over the mountains. That fall and winter over 2,000 people went into the new district and founded the town of Chloride. This town, of which there are now but a few tumbled-down shanties remaining, stood at a forks of the creek about 5 miles above the present town of Lakeview. The boom lasted about a year, and then the stampede element drifted away and only those who had faith in the district remained and continued a systematic development of their holdings.

Mines and properties.—The Webber group of claims lies about 6 miles south of Lakeview, from which place it is reached by a wagon road. The vein is a fault fissure in which the walls have been somewhat replaced by vein material. The fissure runs about east and west, and gives evidence of a considerable displacement. It is associated with a diabasic dike and cuts a country rock of Wallace shale.

On the surface, in the weathered zone, the ore carried free silver to a reported value of about 400 ounces per ton. This led to its acquisition by a company and the installation of a complete free-milling plant. Soon, however, the lead and silver appeared in the sulphide form, and the values could not be saved by such a process. Some shipments were then made to a smelter, but the ores were not of high enough grade to return a profit, and accordingly operations at the mine and mill were suspended.

The Keep Cool group adjoins the Webber property on the west and appears to be on the same vein. A section of the vein here shows a large zone of breccia, gouge, and quartz carrying considerable galena and striking about N. 75° W., with a dip of 75° S.

The Conjecture property lies a mile below the Webber, on the same creek. The country rock, vein, and ore are practically the same as those of the other mines. A free-milling plant was used for the treatment of the rich surface ores.

The Hidden Treasure claim is located on a fissure in limestone which is characterized by a fault of considerable displacement. It is being worked by an open cut which reveals galena of good quality. The Venezuela and Silver Chord had not, at the time of visit, produced any ore.

Production.—The following table shows the estimated amount and value of ore shipped from the district:

Table of ore shipped from the Lakeview district.[a]

Name.	Tons shipped.	Value per ton.	Remarks.
Webber group	Concentrates, 2,000; crude ore, 11,000; now on dump, 6,000.	Lead, $2; gold, $1.50; silver, 24 to 50 ounces.	Idle for some time; hope to resume work when new smelter is built at Sandpoint.
Keep Cool	To the value of about $15,000.		Not working.
Conjecture	To the value of about $70,000.		Do.
Vulcan	50		Do.
Hidden Treasure	50; on dump, 50	Average assay, $40	One man getting out ore.

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[a] This table is based on data kindly furnished by Mr. F. A. Webber.

Outlook.—This district has been proved to contain considerable low-grade silver-lead ore. Under present conditions the operation of the many small properties of the district would be expensive. Cheap production is the question to be solved in this field. Consolidation of interests and work on a large scale would seem to be productive of the best results here and would very probably produce some good dividend-paying properties. The new smelter at Sandpoint will doubtless furnish a better market for the ores than has hitherto been available and will materially encourage further work.

Lime.—Most of the properties of the Washington Brick and Lime Company, of Spokane, are situated within the Lakeview district. A plant of four kilns at Squaw Bay, a few miles from Lakeview, is owned by this company. It has been running fifteen months and has turned out about 75 barrels of lime per day. This product is shipped on scows to Hope and thence to its destination by rail.

A large deposit of very pure gray limestone of uncertain age occurs close by. This deposit, together with others of the same nature which are found in the vicinity, can perhaps never be exhausted by lime-manufacturing plants.

BLACKTAIL MINE.

This property is on the northeastern slope of Blacktail Mountain, a high peak in the ridge which forms the southwestern shore of Lake Pend Oreille.

The vein is in Wallace shale, near to the large Blacktail fault, but is not very clearly defined. A good deal of development work has been done and considerable ore shipped in the past. No recent shipments have been made, however. It was reported that the ore was found in a narrow fissure and was quite rich in silver. Neither assays nor data regarding shipments were available at the time of visit.

EASTERN SHORE.

As the Lakeview district began to decline, the many prospectors it had attracted gradually scattered over the surrounding mountains. The result was that a great number of claims were staked on the eastern shore of Lake Pend Oreille. Many of these were abandoned, but a few are still being developed for their gold content; others are held as future producers of silver and lead. Perhaps the greatest promise, however, is attached to those being slowly developed for their copper values. In spite of the lack of concentrated development work, the district has some promise as a prospecting field and may yet develop shipping properties.

Prospects.—The June Bug is a claim on the east end of Lake Pend Oreille. It is situated a few miles southeast of the point where the Clark Fork empties into the lake. The country rock is green and purple shale. The vein is of white quartz running N. 75° W., with a dip of

80° S. It shows considerable specular hematite, a little bornite, and some chalcopyrite. Not enough development work has been done to disclose any mineralization of commercial importance.

The Pend Oreille copper properties are located near the Northern Pacific Railway, a few miles east of Hope. The country rock is a bluish-gray shale belonging to the Wallace formation. The main lead is about 11 feet wide, and its walls are fairly well defined. It seems to trend about N. 55° E. and to dip 80° E. The croppings show cupriferous pyrite, but the vein has not been sufficiently opened to reveal its extent and value.

TROY.

Troy is a small Montana town on the Great Northern Railway. It is in the Kootenai Valley, at the foot of the Cabinet Mountains, and is the natural distributing point for the mining properties on Callahan Creek and Grouse Mountain.

CALLAHAN CREEK.[a]

On Callahan Creek are two lead-zinc properties on fissure veins which promise to become producers of some importance. There is also a prospect farther up the creek than these, in what was considered by one observer to be a contact deposit. This, however, was not visited, so that attention may be confined to the two properties first mentioned, the Big Eight and B & B mines.

The ore bodies in which these mines are located occupy fissures, but igneous agencies have been concerned in their formation, and they have a composition characteristic of contact deposits rather than of ordinary fissure veins. The B & B and Big Eight are situated on the same fissure or on two parallel and only slightly separated fissures of the same system with a course of about N. 30° W. These breaks are subsidiary to a great fault which passes between the mines and Troy and brings Wallace and Striped Peak rocks on the east down against Creston quartzite and Prichard slate on the west. The country rock of the B & B mine is typical Prichard slate; that of the Big Eight is a grayish quartzitic material probably belonging to the Creston quartzite. Penetrating these sedimentaries and injected in the fissure occupied by the vein, there is in each of the mines a basic dike, so far altered that its original petrographic character can not be satisfactorily determined. The mineralization seems to have been posterior to, but was possibly in part contemporaneous with, the intrusion of the dike.

In the Big Eight mine the vein is just west of the dike. It is about 8 feet wide, with walls fairly well defined. The ore is rather irregularly distributed, in places forming most of the vein, but often mixed with much gangue material and masses of country rock. It is principally sphalerite, which forms large masses of great purity, but is locally mixed with a subordinate quantity of galena. The gangue is the most remarkable feature of the vein, and consists chiefly of silicates, including a pale-greenish amphibole, garnet, biotite, and chlorite. Calcite and a little pyrite occur locally. About 200 feet east of and parallel to the main vein is a small vein of nearly pure galena.

The B & B vein has practically the same characteristics as the main vein of the Big Eight. The gangue is likewise chiefly a mixture of silicates, and the valuable minerals consist of sphalerite and galena.

Neither property was shipping ore when visited, although both have shipped considerable amounts in the past. The B & B was idle, owing, it was reported, to litigation. The Big Eight was being worked under a lease held by the Batchelder Brothers of Spokane, and had about 150 tons of ore on the dump.

GROUSE MOUNTAIN PROPERTIES.

Grouse Mountain is a spur of the Cabinet Range, lying between the headwaters of Callahan and Lake creeks.

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[a] This region was visited and described by Mr. Calkins.

The Great Northwestern property is situated on the southwestern slope of the mountain. The country rock is grayish siliceous shale, probably of the Prichard formation, which is cut by a large diabase dike trending northwest and southeast. A fracture zone parallel to and lying within this dike forms the vein. It is filled with white quartz, calcite, and iron-stained breccia, is from 2 to 6 feet wide, and carries galena, some iron pyrite, marcasite, siderite, sphalerite, and a few crystals of chalcopyrite. The ore is said to carry from 18 to 50 ounces of silver per ton and seems to occur in irregular bunches. The vein appears to be richer where it is cut by a porphyry dike of later origin. About 60 tons of ore are on the dump awaiting the construction of a wagon road to Troy, 12 miles distant.

The Iron Cap property adjoins the Great Northwestern and seems to be on the same lead, which here cuts typical Prichard slate. It has been opened up by a shallow open cut, exposing a large amount of iron capping and crushed vein material. Some pieces of galena are found throughout the less weathered parts.

FUTURE PROSPECTS.

Though comparatively young, the Troy district shows considerable promise. The veins seem to be strong and development work may show ore bodies of considerable extent. In spite of the fact that some of the ores carry zinc, wisely directed operations should produce some paying mines.

SYLVANITE.

Location.—Sylvanite is situated in the Loop Mountains on Yaak River, about 20 miles north of the point where it unites with the Kootenai.

Mines and properties.—The Keystone and Goldflint, situated on the same lead, are the two principal properties in the district. The country rock is Creston quartzite. In being folded to its present form certain hard beds have slipped over the softer beds. Between two such folded beds lies the vein, which has a filling of white quartz and iron-stained crushed rock.

The extent of the workings would indicate that the mine had produced considerable free-milling gold ore. This ore was concentrated in a 10-stamp mill. The property is now idle, owing, it is reported, to litigation. Base ore which could not be treated by the free-milling process, may, however, have been found with depth.

SNOWSHOE MINE.

General statement.—The Snowshoe mine, owned by the Rustler Mining and Milling Company of Pittsburg, comprises three patented claims, the Snowshoe, Rustler, and Porcupine. Information regarding the output, values, etc., of the mine was courteously afforded by the manager.

Location.—The Snowshoe mine is situated in the most precipitous and rugged part of the Cabinet Range. It is at the head of Libby Creek and just across the divide from Bull Lake.

A good wagon road down Libby Creek connects the mine with the Northern Pacific at Libby, about 22 miles to the north. Several four and six horse teams haul the ore out and bring in the supplies over this road.

Geology.—The Snowshoe vein occupies the fissure of a large, clean-broken fault. The country rock on the east side of the fault is a grayish-green to dark-gray massive shale of the Burke formation, and on the west side a calcareous shale of the Wallace formation. This shows that a throw of several thousand feet has occurred. Owing, however, to the fact that the fissure is here almost perpendicular, there has been a minimum of friction and very little gouge has been formed.

The vein is clearly defined, has almost perpendicular walls, and trends north and south. Another smaller vein lies about 75 feet east of the main lead and almost parallel to it. The filling material is principally white quartz and crushed rock, with a few inches of shiny black talcose parting on the east and a little greenish-blue gouge on the west wall.

Development work has opened up 300 or 400 feet of depth on the vein, showing lenticular masses of galena and an average width of about 7 feet.

Ores.—The ore is a silver-bearing galena, carrying a gold value of about $1.50 per ton, which is said to increase with depth. An average assay shows about 10 per cent lead and 5 ounces of silver per ton. This ore, concentrated approximately 6 or 7 into 1, yields about 50 per cent lead, 25 ounces of silver, and $5 to $10 in gold. In view of the long wagon haul it is very desirable that the concentration be carried as far as possible. This results in the loss of a large proportion of the gold values, probably as high as $400 per day. The mine has shipped to date about $850,000 worth of ore, mainly to the smelter at Everett, Wash.

Plant.—The concentrating plant is driven by water power, except the compressor and electric-light plant, which during the dry season are driven by steam.

The water power is now obtained by damming water in glacial cirques above the mine. This storage could be greatly increased and a considerable saving on steam thus effected by improving the position and increasing the size of the dams.

Future prospects.—This property is now the leading producer in the district, and it gives strong indications of a considerably increased output before long. The great lead on which it is located is traceable for some miles, and is being explored in several of the numerous claims staked along its course. If the present development continues, a branch from the main line of the Great Northern Railway may soon be warranted. Such a branch line could easily and cheaply be built up the gentle grade of Libby Creek. It would pass through excellent timber land and would greatly encourage mining in the district.

CABINET DISTRICT.

Location.—The Cabinet district lies in the Cabinet Mountains about 20 miles southeast of the Snowshoe mine. It comprises the properties on Silver Butte Mountain and those on the headwaters of Fisher River. The former are reached from Trout Creek, on the Northern Pacific Railway, by a wagon road about 15 miles long up Vermilion Creek. Entrance into the Fisher River country is by wagon road from Libby, some 25 miles to the northwest, its nearest railway point.

SILVER BUTTE MINE.

The Silver Butte property is located on a vein which strikes N. 60° W. and dips 30° S. and cuts across Silver Butte Mountain.

The country rock is blue Prichard slate carrying some beds of grayish arenaceous shale. The vein averages 10 feet in width, but an outcrop on top of the mountain shows white quartz to the width of 30 feet, which can be traced for about half a mile. The ore is composed of galena, which is scattered through lenses of white quartz. Some sections of the vein show only barren white quartz, crushed country rock, and gouge.

In a concentrating plant erected at a reported cost of $150,000, some ore has been milled. While temporarily closed down this plant was burned to the ground and the mine has since been idle.

Outlook.—This property is located on a strong quartz vein. The exploration work done has exposed values enough to indicate that systematic development work might open up sufficient low-grade silver-lead ore to make the property a regular producer. Several other locations are on what appears to be the same vein, but as yet little work has been done on them.

FISHER RIVER PROPERTIES.[a]

Just across the divide of the Cabinet Range, in the Fisher River drainage, about north of Silver Butte, is a group of properties which were once sufficiently productive to have led to the construction of three stamp mills, but they are now almost completely abandoned. None of them were entered in the course of this reconnaissance, but their general character was observed. The lodes are all in typical Prichard slate and have the form of blanket veins parallel to the stratification. The vein material is chiefly quartz, with pyrite and gold, forming a rather low-grade ore which has apparently failed to yield profits below the zone of oxidation.

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[a] Visited and described by Mr. Calkins.

PROSPECT CREEK.

Location.—Prospect Creek heads in the Cœur d'Alene Mountains near Thompson Pass. It flows into Clark Fork near Thompson Falls, and is just across the divide to the northeast of the Cœur d'Alene mining district.

Mines and properties.—The Rosebud Mining Company is exploring several claims near the mouth of Rosebud Creek, a small tributary which enters Prospect Creek about 9 miles above its mouth. A vein of white quartz has been found by this company in the upper part of the Prichard formation. One of the owners reports that it carries some silver chloride and over $100 per ton in gold in the weathered zone at the surface.

The Montana Standard group of four claims is on Prospect Creek about 11 miles above its mouth. The vein is associated with a massive basic dike which cuts a country rock of the Burke formation. An adit driven on the east contact of this dike shows irregular masses of white quartz carrying galena. About 400 feet from the mouth of this tunnel a fairly well-defined cross lead runs N. 20° E. and dips 70° E. It shows some evidence of shearing and carries galena and siderite. On the west side of the dike a flat vein outcrops. It is 3 to 4 feet thick, strikes about N. 15° E. and dips 15° W. No connection between this vein and the ore deposit on the east side of the dike was apparent. The ore seems to lie in irregular bunches and cross fissures along the east contact of the dike. The examination of this property was very hurried, but it would seem advisable in the course of the present active development work to explore the east contact of the dike.

A few miles farther up Prospect Creek an antimony vein occurs from which a considerable amount of ore is said to have been shipped some years ago. This property is now idle. Other claims have been located on this creek, but very little development work has been done on them. A wagon road to Thompson Falls and Murray furnishes convenient access to the region.

MINING PROPERTIES NOT VISITED.

The Buckhorn, a few miles east of Mooyie River and about 10 miles above its mouth, is a producer of gold and shows some lead. So far as present development has gone the ore is free milling. A 10-stamp mill has recently been installed and shipments were expected to begin shortly. Some copper properties were reported to have been prospected at the headwaters of Bull River, but very little actual development work has been done on them. On Rainy Creek north of Libby is a prospect in a contact deposit from which some fair samples of galena have been taken.

MISSOULA VALLEY.[a]

The valley of Missoula River below Missoula has been and is still, though perhaps to a lesser extent than formerly, the scene of considerable mining activity. Large amounts of gold have been taken from placers on the tributaries. Copper deposits are being developed in the mountains south of the river, but their future value can not as yet be predicted with confidence. North of the river the veins are chiefly of galena, but few of these have been developed. The only property visited was the Iron Mountain mine, situated about 5 miles north of Iron Mountain station on the Northern Pacific Railway.

IRON MOUNTAIN MINE.

This property, once the most important in the district, is now idle. It began to produce about fourteen years ago and was worked for about eight years, during which period it yielded about half a million dollars in dividends besides paying the expenses of mine development, the building of a 200-ton mill, and the construction of about 15 miles of mountain road. The closing of the mine was due to the enactment of a State law which requires that every mine shall have two openings. It has now been determined to comply with this law by the construction on the 1,500-foot level of a tunnel which will be over a mile in length.

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[a] Visited and described by Mr. Calkins.

The surveys for the tunnel have been completed, and its construction actually begun, so that in the near future the mine will probably resume its place as a producer.

The ore body is a fissure vein about 3 feet in average width, striking about northwest and dipping steeply to the northeast. The country rock is somewhat calcareous light-green shale of the Wallace formation. The ore is argentiferous galena with a little sphalerite carrying about 6 ounces of silver to the ton. The concentrates constitute about 45 per cent of the ore as mined.

SUMMARY.

In regard to the region as a whole, the similarity of its rocks to those of the Cœur d'Alene district, together with its position between that district and the great producing mines of southern British Columbia, may well mark it as a promising field for the prospector. Moreover, large faults and their accompanying smaller fractures afford great systems of circulation for underground waters and greatly increase the opportunities for ore deposition in those fissures which present the proper conditions. Dikes, which in other mining regions have also been recognized as indicative of mineralized conditions, are abundant.

In conclusion, the reconnaissance has left a strong impression that systematic and wisely directed work in this region will yield good results.

NOTES ON ORE DEPOSITS OF SOUTHWESTERN NEVADA AND EASTERN CALIFORNIA.

By Sydney H. Ball.

INTRODUCTION.

During the summer and fall of 1905 topographic parties under Mr. R. H. Chapman made a reconnaissance topographic map of an area in southwestern Nevada and eastern California. The writer was attached to the parties as geologist, under the general supervision of Mr. F. L. Ransome.

The topographic map is on a scale of 1:253,440 (4 miles to the inch), with contour intervals of 100 feet, and covers the area lying between 36° 30′ and 38° north latitude and 116° and 117° 30′ west longitude. This area, embracing within its limits 8,550 square miles, is the equivalent of nine of the usual 30-minute quadrangles of the Geologic Atlas of the United States.

The territory surveyed was so great that in many cases only the most hasty examination of a single group of claims in a district was possible, and naturally an attempt was made to select representative groups. But little mining development has as yet been done, and extensive underground workings were nowhere accessible. With few exceptions, the rocks, fossils, and ores have not been examined in the office and the names employed are wholly tentative. The assay values given are those reported by the prospectors, and in most cases represent picked samples. A forthcoming bulletin on the geology of the area will be accompanied by adequate maps outlining the areas especially favorable for prospecting.

GEOGRAPHY.

The area surveyed lies in the Great Basin, and includes portions of Esmeralda and Nye counties, Nev., and Inyo County, Cal. The mountain ranges of the eastern portion of the area have a north-south trend, while the Panamint and Grapevine ranges in the western portion course north-northwest, more nearly parallel to the crest line of the Sierra Nevada. The highest peaks reach an altitude of over 9,000 feet. Between the mountains are broad inclosed valleys, covered by recent sands and gravels. Most of these valleys are from 3,000 to 5,000 feet above sea level, but that portion of Death Valley which lies within the area covered by the map sinks to 280 feet below sea level.

Tonopah, a prosperous mining town and the county seat of Nye County, lies 4 miles north of the area, and is the shipping point for some of the northern and northeastern camps here described. The central portion is tributary to Goldfield, where there are valuable gold mines. This town has 6,000 to 8,000 inhabitants, and is the present railroad terminus. The southern camps have the sister towns of Bullfrog, Rhyolite, and Beatty as supply points.

Goldfield and Tonopah have broad-gage railroad connections with the Union Pacific Railroad. The Carson and Colorado Railroad is from 25 to 45 miles west of the area's western border, and the San Pedro, Salt Lake and Los Angeles Railroad lies 40 to 75 miles east of its eastern border. A railroad has been surveyed from Goldfield to Bullfrog, and two roads are projected from the San Pedro, Salt Lake and Los Angeles Railroad to the same point.

ECONOMIC CONDITIONS.

The various camps herein described, the locations of which are shown on the sketch map, fig. 3, are connected with the supply points by wagon roads, most of them surprisingly good, considering the fact that many are less than a year old. Some mines have a small, but for the present sufficient, water supply near at hand. Other camps are compelled to haul their water from seeps 20 miles distant. Piñon and juniper grow sparsely above an altitude of 6,000 feet. They are rarely of sufficient size for mine timbers other than stulls, but the former makes an excellent fuel. The power question will probably be solved at the successful camps, as it has been at Goldfield, by the transmission of electric power generated on the swift streams of the Sierra Nevada. The heat of July and August renders surface work almost impossible in the more southern camps.

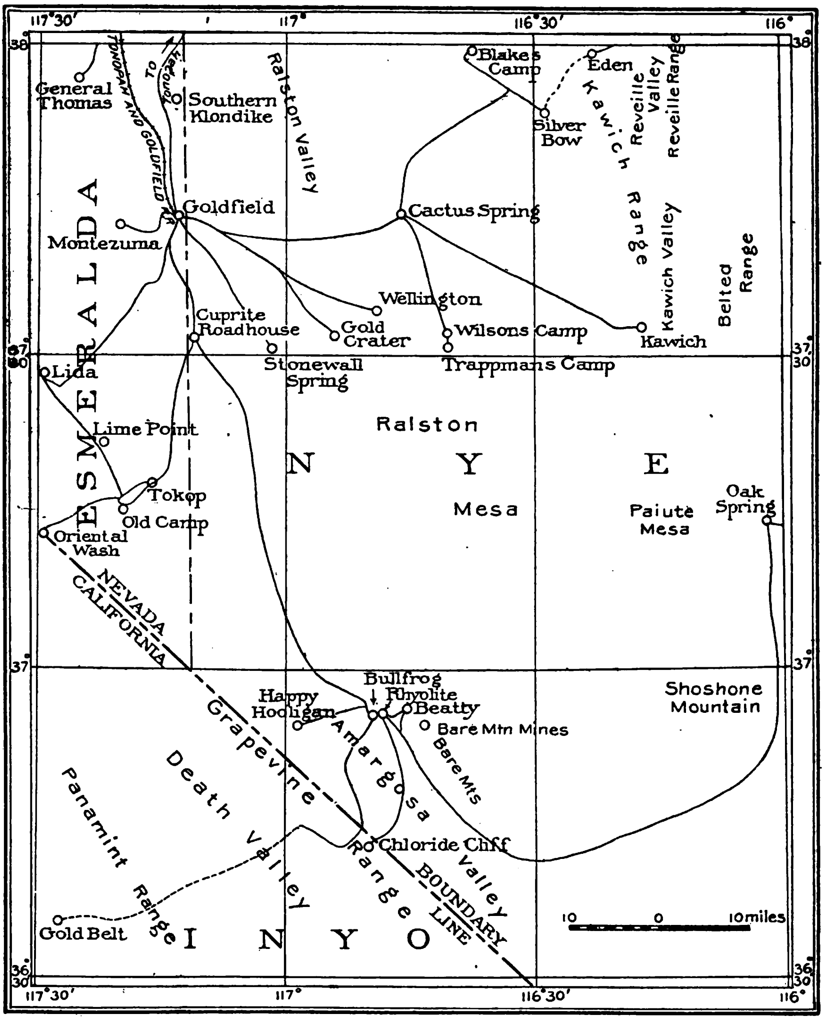

FIG. 3.—Sketch map of southwestern Nevada and eastern California, showing location of mining camps.

GENERAL GEOLOGY.

The barest outline of the geology will be sufficient for present needs. Sedimentation, with few important breaks, extended from the Cambrian period to the end of the Carboniferous. The rocks appear to have been predominantly deposited in rather shallow seas, and include limestones, usually dark in color, quartzites of medium grain, and shales, often olive-green in color. In probably post-Jurassic time these rocks were injected by granites, now widely distributed throughout the area, and diorites, which are largely confined to the western portion. The age difference between these holocrystalline rocks is not great, and there is evidence which points to their possible origin by differentiation from a common magma. Contemporaneously with the intrusion mountains were formed or possibly preexisting mountains were elevated. The intrusion was accompanied by buckling of the strata, reversed faulting, and considerable metamorphism of the sedimentary rocks near the granite contact.

During the latter part of Mesozoic time the mountains were subjected to long-continued erosion, and at the end of the period surface irregularities were undoubtedly less accentuated than now.

In Tertiary time a long period of volcanism was inaugurated. Rhyolite and andesite in flows, sheets, and dikes followed one another repeatedly. Tuffaceous facies are rather common. Possibly in Miocene time considerable portions of the lower regions were covered by lakes which were contemporaneous with basalt flows. Then rhyolitic and andesitic eruptions followed. The Tertiary eruptions were accompanied by subaerial erosion, normal faulting, tilting, and flexing.

In recent time erosion has continued and great thicknesses of gravel and sand have been washed into the valleys as a result of cloudbursts, filling the inclosed basins as we now see them.

The ore deposits so far as known occur in the Paleozoic sedimentary rocks, the granite and diorite, and the older Tertiary eruptives.

HISTORY OF MINING DEVELOPMENT.

Two waves of activity in prospecting have passed over the portions of Nevada and California under consideration. The first started in the late sixties, reached its maximum height in the seventies, and died out before 1890. The hardy prospector and miner in these years confined his attention to the limestone and granite. Lida, Old Camp, and Montezuma were flourishing mining centers.

Mining in the areas studied was dormant in the nineties, but with the discovery of Tonopah's phenomenal ore bodies in 1900 the desert region was attacked with new ardor. The Tertiary eruptives have been more especially the chosen field of the prospector, although the limestones and granites have been by no means neglected. Goldfield and Bullfrog, the most important new camps, are now being studied in detail by Mr. F. L. Ransome and his assistants, Messrs. Emmons and Garrey, and will be the subjects of future Survey publications. Notes on the outlying districts only are embodied herein.

GENERAL CHARACTER OF THE ORE DEPOSITS.

The ore deposits herein described are apparently the work of two distinct main periods of mineralization—one post-Jurassic and probably pre-Tertiary, the other Tertiary. The veins at Chloride Cliff may, indeed, be even pre-Jurassic, but their resemblance to the post-Jurassic veins renders this questionable.

POST-JURASSIC AND PRE-TERTIARY DEPOSITS.

Deposits in granite.—(1) Pegmatitic dikes: Dikes of pegmatite at Oak Springs are reported to carry gold and silver values.

(2) Reopened pegmatitic dikes: The quartz, itself of pegmatitic origin, has been crushed, and the values are probably due to the same period of mineralization as that which formed the deposits next described (3). The deposits at Lime Point and some of those at Trappmans Camp are of this origin.

(3) Massive quartz veins in fissures, joints, and irregular zones of brecciation: The quartz is not crustified. The chief sulphide is pyrite, although galena, chalcopyrite, and sphalerite sometimes occur. The deposits are usually gold bearing, although with the introduction of galena silver values may predominate. These ores were deposited by water, which may have been remotely connected with the granitic intrusion. Such appear to be the deposits at Old Camp and some of those at Trappmans Camp, Oak Spring, and Southern Klondike.

(4) Impregnation of pyrite along joints: This is an unimportant form of deposit and is seen only at Trappmans Camp.

Deposits in diorite.—(1) Quartz veins: This is the type of deposit at Gold Belt, and is similar in form and mineral paragenesis to the deposits described in the next paragraph.

Deposits in Paleozoic sedimentary rocks, predominantly limestone.—(1) Quartz veins and irregular masses occupying faults, joints, bedding planes, and brecciated zones, usually in the neighborhood of granitic intrusions. Rarely a little calcite is associated with the quartz. The original sulphides deposited in the quartz include chalcopyrite, galena, pyrite, and sphalerite. In the veins in limestone the predominant sulphides are chalcopyrite and galena, and the values are largely silver. In quartzite and schist, in lime-silicate rocks, composed of quartz, garnet, and epidote, and in limestone zones in which silicification extended beyond the quartz vein, pyrite is the predominant sulphide, with gold values alone or in excess of silver. It is probable that the relative abundance and variety of sulphides was determined by the wall rock, the more siliceous rock tending to precipitate from the waters auriferous pyrite, the calcareous rock precipitating argentiferous galena and chalcopyrite. The secondary ores of this subdivision include malachite, azurite, chrysocolla, native copper, brochantite, cerussite, native gold, and horn silver, while chlorobromides of silver are reported. Chalcocite is probably of secondary origin. Two or more of these ores are associated with hematite and limonite or with a heavily stained jaspery quartz with conchoidal fracture. Gypsum and at one place sulphur are gangues of less wide distribution. Cavities in the secondary ores are often frosted by later quartz crystals. The Tokop veins belong to this subdivision, and their similarity to veins in the granite of Old Camp and their reported passing into the granite beneath indicate that the quartz veins in the granite and limestone are contemporaneous in age and of like origin. The Lida, Bare Mountain, and Oriental Wash deposits and some of those of Chloride Cliff, Montezuma, Oak Springs, and Southern Klondike are of this type.

(2) Veins following contacts. These occur in limestone along diorite-porphyry dikes and sheets and at Chloride Cliff along a mass of hornblende-gneiss. The diorite-porphyry is, without much doubt, pre-Tertiary, and the mineral association so similar to that in the deposits just described (1) that there can be but small doubt of the contemporaneous origin of the two from the same waters. The General Thomas and some of the Montezuma prospects are of this type.

(3) Replacement deposits: In the Cuprite mining district and to a less extent in the General Thomas mine the sulphides appear to replace the limestone in irregular masses. The Cuprite deposits are at a considerable distance from the granite masses, and in these deposits quartz is rare. The same secondary minerals are found here as in other deposits in the sedimentary rocks.

TERTIARY DEPOSITS.

Gold deposits in silicified monzonites.—Gold occurs at Kawich and Gold Crater in silicified and kaolinized monzonitic rocks. When the monzonitic rock was silicified pyrite was deposited in open fissures in it, and probably partially replaced the monzonite. Disseminated pyrite occurs beyond the silicified zone. During the surface alteration of the pyrite free gold lodged in the cavities of the altered monzonite and at Gold Crater was deposited along joints in the surrounding iron-stained monzonites.

Deposits in rhyolite.—(1) Silver and gold bearing quartz veins in silicified and kaolinized rhyolite: At Silverbow, Eden, Cactus Spring, Wilsons Camp, Stonewall Mountains, and Wellington vuggy quartz veins, often with crustification well developed, fill fault fissures, joint planes, and cavities of brecciation and solution. These deposits, if not demonstrably of contemporaneous origin, were formed by similar solutions. The original sulphides include stephanite, iron pyrites, and chalcopyrite. Pyrargyrite, also noted, may be secondary. From the primary ores free gold, horn silver, malachite, azurite, limonite, and hematite are derived. The relative abundance of silver sulphides or of pyrite determines whether the veins carry predominant silver or gold values. In the same camp structurally similar veins carry, respectively, gold and silver, and in various portions of the same vein the proportion of the two metals varies greatly. These deposits are evidently the work of ascending waters, which deposited quartz and sulphides in open crevices. The silicification and mineralization extended in many instances beyond the walls of the crevices.

(2) Gold ores in fault zones: At Blakes Camp free gold has been panned from crushed rhyolite along a fault. The iron pyrite was probably originally disseminated in the crushed zone.

(3) Gold ores along Tertiary lava and limestone contacts: A quartz vein at Southern Klondike is situated along the contact of rhyolite with Cambrian limestone. At the Happy Hooligan mine free gold occurs in decomposed rock at the contact of basalt with Ordovician limestone.

Relative ages of the Tertiary deposits.—It is believed that the first two subdivisions of the ore deposits in rhyolite are contemporaneous, while the third may be so also. The relative ages of the deposits in monzonitic rocks and rhyolite are unknown The monzonite is older than the rhyolite, but the deposits may be of approximately contemporaneous age.

DESCRIPTION OF CAMPS.

The description of the camps is arranged by counties, since in many camps several types of ore deposits occur. The mines of Esmeralda County are described in order from north to south. In Nye County the mines of the Kawich Range (Silverbow, Eden, Blakes Camp, and Kawich) are first described; then those of the Cactus Range (Cactus Spring and Wellington); next those of the Ralston Mesa (Trappmans Camp, Wilsons Camp, and Gold Crater), and lastly the remaining camps in the county.

ESMERALDA COUNTY, NEV.

Foothills of Lone Mountain.—In the northwest corner of the area surveyed and separated from the main mass of Lone Mountain to the northwest are hills whose borders are cut by narrow canyons. The Cambrian limestones and shales are here complexly folded, although the major folds have axes coursing from northeast to southwest. The sedimentaries are cut by irregular masses of diorite and by dikes and sheets of diorite-porphyry.

When visited by the writer in June, 1905, the General Thomas mine, of the Tonopah-Belcher Mining Company, was closed down. Several inclines follow the steeply dipping beds of limestone and shale, which in the vicinity are injected by sheets of diorite-porphyry. Cerussite, malachite, azurite, and chrysocolla in altered limestone heavily stained by limonite were seen on the dump. Gypsum was simultaneously formed with the secondary minerals. Galena and pyrite in calcite were the only original sulphides seen, but some copper sulphide must also occur. Mr. Arthur Lakes[a] states that lenticular bodies of "sand" carbonate of lead containing nodules of unaltered galena lay along the contact of porphyry and limestone, as well as in the limestone itself. The ore is said to carry high silver values. A carload shipment made in January, 1904, netted $4,300. At that time the shaft was 150 feet deep. This deposit resembles some of those at Montezuma. Other prospects occur in limestone and in the diorite in the vicinity. The surrounding hills are bare of timber, and water is scarce. Tonopah, the supply point, is 12 miles distant by road.

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[a] Min. and Sci. Press, vol. 88, p. 246.

Southern Klondike.—Southern Klondike is 12 miles north of Goldfield and an equal distance south of Tonopah. Gold and silver ores were discovered here in March, 1899, by Messrs. J. G. Court and T. J. Bell. Work has been carried on more or less continuously since that date. From one group of claims shipments of ore averaging $200 a ton and aggregating $50,000 are reported. Several thousand feet of tunnels, shafts, and inclines have been driven. In June, 1905 (the time of the writer's visit), eight men were at work in the camp.

The hills surrounding the camp are cones and ridges of low relief. The predominant formation is a black Cambrian limestone, locally silicified to a dark jasperoid. Associated with this are minor quartzite lenses and beds of partially metamorphosed shale. The sedimentaries are folded into an anticline with a northeast-southwest axis. While some vertical beds occur, moderate dips predominate. Small dikes and irregular masses of muscovite granite inject the Cambrian rocks. The granite is probably of post-Jurassic age. Tertiary flows and dikes of rhyolite respectively cap and cut the sediments.

The ore deposits are of three kinds—first, quartz veins parallel to the bedding of the Cambrian rocks; second, quartz veins carrying predominant gold values along the contact of the sedimentaries with quartz-rhyolite dikes; third, quartz veins in granite along joint fractures. The last-named veins carry silver-bearing lead ores (galena and cerussite). The contact veins show post-mineral faulting.

The quartz veins parallel to the bedding planes of the limestones are of greatest value and interest, and these only will be described. They are tabular lenses of quartz from a few inches to a foot or more in thickness. Horses of limestone are included. Adjacent veins connected by cross veins of quartz or completely separated by thin bands of limestone may form a mineralized zone 14 feet thick. The quartz appears to have filled a fissure in the limestone. Brecciation of the limestone accompanied the fissuring. The contact between the limestone and quartz is sharp, and silicification of the limestone has not occurred to an important extent. Vugs lined with quartz crystals are rather characteristic of the white, semitransparent quartz.

The original sulphides deposited simultaneously with the quartz and disseminated in small masses in it are, in the order of their abundance, galena, stetefeldtite,[a] and iron pyrites, The secondary ores include horn silver, chrysocolla, malachite, azurite, specular hematite, and cerussite in brownish granular masses and to a less extent in crystals. These secondary minerals surround the sulphides and fill cavities and cracks in the quartz. Some calcite and gypsum, accompanied by sulphur, are secondary gangue minerals. Sulphur sometimes forms masses 3 inches in diameter. Assay returns show from 25 to 40 per cent of the values in gold, the rest in silver. Silver occurs as the chloride and apparently also associated with the copper minerals. The prospects as yet are well above water level.

In southern Klondike fissures and brecciated zones were opened in the Cambrian limestone along bedding planes. Water filled these cavities with silica and with lead, copper, and iron sulphides carrying silver and gold. The quartz veins have since been fractured and faulted and surface waters have developed a number of secondary minerals. In this district the presence of quartz veins at the contact of rhyolite and limestone shows the Tertiary or post-Tertiary age of the gold veins, but the presumption is that the more important silver veins are of earlier formation.

Water is obtained at the Klondike wells 4 miles distant. When visited, Tonopah was the supply and shipping point.

Montezuma district.—Montezuma is situated 8 miles nearly west of Goldfield. The Montezuma mining district was organized in 1867, and soon afterwards several mines were opened in the country west of Montezuma Peak. In the eighties a mill was erected in the gulch to the northwest of the mountain. Active work ceased in 1887, but at present a number of prospectors are reopening old properties and locating new claims. The district product, estimated at $500,000, was freighted in wagons to Belmont, 65 miles away. At present only a few shallow prospect holes and the dumps of the old mines are accessible for examination.

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[a] Copper-silver sulphide reported by J. E. Spurr: Trans. Am. Inst. Min. Eng., 1905, p. 961.

The Montezuma hills are a rugged spur of the Silver Peak Range, the highest point being Montezuma Peak. The mineralized area lies to the west of this mountain in Cambrian sedimentary rocks. Compact, fine-grained, black limestone, intimately cut by quartz and calcite veinlets, predominates over light-colored quartzites and green shales. The Cambrian is cut by diorite-porphyry and quartz-latite dikes. The folding of the sedimentary rocks is rather gentle, although local buckling of the strata is observed. The productive area is surrounded by nonmineralized Tertiary lavas and sediments.

In the old mines the chief gangue is quartz, with rarely a little calcite and kaolinitic material associated. Vugs filled with quartz crystals occur in the quartz. The ores at the surface are cerussite, malachite, azurite, and limonite, and associated with these and replacing them in depth are galena, chalcocite, and pyrite. The values are largely in silver, the gold values being uniformly low. Chlorobromides of silver are reported, but were not seen.

A prospect hole exposes a quartz vein with a diorite-porphyry dike as hanging wall and limestone as foot wall. Chalcopyrite is the original sulphide, and malachite with less limonite, azurite, and a little native copper are the secondary ores. The native copper forms knife-edges in cracks and small nodules in the vein. Malachite partially replacing limestone was noted at a number of other places.

Copper and lead sulphides with quartz fill open fissures in limestone. Some, probably all, of the deposition followed the dike injection, of probably pre-Tertiary age. Later the veins were crushed and surface waters altered the sulphides to carbonates, oxides, native metals, and probably minerals of the haloid series. That the chemical breakdown of the sulphides is continuing is indicated by the water flowing from an abandoned tunnel southwest of the mill; this deposits considerable limonite and is so charged with ferrous sulphate that animals will scarcely drink it.

In several of the older mines and prospects, water, some of which is suitable for domestic purposes, was encountered at a depth of 30 feet. The mines will probably require pumps, but abundant fuel surrounds them. Goldfield, the railroad terminus, is 9 miles distant, the road being fairly good.

Cuprite.—The copper prospects of the Cuprite mining district lie in a belt 1 mile wide which extends from a point 17 miles south of Goldfield westward to Mount Jackson. The district is a new one, the first locations having been made early in 1905. The mines lie from 2 to 9 miles west of the stage and automobile road between Goldfield and Bullfrog.

The low hills in which the mines lie are composed of Cambrian sedimentary rocks and flows of later eruptives. The Cambrian rocks are, as usual, predominantly limestones of black color and rather fine grain, and subordinately green shale, often paper thin, with semischistose facies. The limestone and shales are gently folded, the predominant dip being westward. Minor normal faults, in some instances intimately connected with the ore deposits, are common. The Cambrian at Cuprite, as at Lida, is cut by dikes of diorite-porphyry. Here also these appear to have no intimate connection with the ore deposits. To the north of the copper belt rhyolitic rocks cover considerable areas. Residual areas of later basalt flows of no economic importance cover both the Cambrian and rhyolite at a number of localities.

The properties of the Goldfield-Midway-Bullfrog Mining Company and the Tri-Metallic Mining Company may be taken as types of the copper properties of the Cuprite mining district.

The Copper Bell shaft of the first-named company is located on the side of a gentle valley in Cambrian sedimentary rocks and is now 85 feet deep. The shaft is being sunk to encounter a vein which strikes N. 60° E. and dips from 80°-85° NW. This vein has been traced by means of prospect holes at least 1,000 feet. At one prospect hole the vein is capped by a gossan of spongy limonite 9 feet thick. At this depth some malachite and less azurite are associated with the limonite, and at the bottom of the hole, 9 feet deeper, the vein is reported to have run 12 per cent copper, with 14 ounces of silver and $1.20 in gold per ton. The vein is from 2 to 5 feet wide and on its borders shows a gradual passage from totally unaltered limestone to pure limonite. These secondary ores, on the border of the vein, at least, are a replacement of the limestone. The same company has an incline 65 feet deep situated on a shear zone in practically horizontal limestone. The shear zone strikes N. 85° E. and dips 60° S. A streak of ore, traceable more or less continuously for 900 feet and from 1½ to 2½ feet wide, occupies the shear zone. The ore consists of malachite, azurite, and limonite, associated with intensely limonite-stained chalcedony of conchoidal fracture. The sulphides seen were chalcocite and, in less amount, chalcopyrite and pyrite. The two latter are undoubtedly original. Several assays of the ore are said to have averaged between 9 and 10 per cent of copper, while the silver values are variable, reaching as high as 400 ounces per ton. The silver is evidently intimately associated with the copper minerals, the iron compounds giving no silver returns. The average ore runs, per ton, about 1 ounce of silver to 1 per cent of copper. Gold is present in traces only. Another prospect on this property is in limestone much stained by limonite. Malachite and less azurite with a heavily limonite-stained chalcedonic quartz occur in small "kidneys" throughout the limestone and in narrow seams along joint planes. Chalcopyrite is reported from the surface here, but is not abundant. In another prospect irregular lenses of the same ores and gangue lie in a narrow shear zone in the limestone. Small bunches of chalcopyrite are sporadically distributed in the dark chalcedony.

The property of the Tri-Metallic Mining Company lies one-half mile west of that last described. The Cambrian limestone, although gently flexed, is approximately horizontal. Intense staining by limonite is characteristic of limestone in the vicinity of the ore. Minor faults were noted, but their association with the ore deposits is not intimate. A shipment of picked ore, which netted $236 per ton (averaging 7 ounces of gold, 230 ounces of silver, and 19 per cent of copper), was recently made from a surface pocket of ore. Chalcopyrite is the only original sulphide present. Chalcocite, malachite, and azurite with dark-brown chalcedony are secondary and these are partially at least replacements of limestone. A few masses of native copper, presumably of secondary origin, are also reported, although they were not seen by the writer. Chalcopyrite was apparently originally distributed in the limestone in masses, which so far as known do not exceed one-half inch in diameter. Later these scattered particles were concentrated, the secondary copper minerals apparently being replacements of limestone.

In the main shaft bunches of chalcopyrite lie in the limestone in association with coarse calcite much stained by limonite. In some cases the chalcopyrite has been brecciated and the narrow interstices filled with iron-stained chalcedony. The ore in this shaft is said to have occurred in "kidneys," sometimes connected with other "kidneys" by narrow ore seams. From one of these masses 1,900 pounds of ore were removed. This lens of ore was 4 feet in diameter at the center and tapered to a point at each end, the total length being 9 feet.

Ore examined from a claim owned by Mr. E. Oldt showed similar characteristics, a little galena and white quartz of apparently equal age being associated with pyrite and chalcopyrite. Again, transparent drusy quartz crystals contemporaneous with or later than the copper and lead carbonates and brown chalcedony are characteristic. The values in this ore are said to be in silver and copper.

In the Cuprite district chalcopyrite with less pyrite, galena, calcite, and quartz appear to have been deposited as sporadic masses in the limestone, as seams along joints, and as lens-shaped bodies along shear zones. Later these ores were altered by descending waters to chalcocite, carbonates, and oxides, the carbonates and oxides in large part replacing limestone. Faulting often accompanied or preceded the change. Contemporaneously a heavily iron-stained chalcedony was deposited in intimate association with the oxidized ores. Later, in some instances, drusy quartz was deposited upon the copper carbonates. The development is altogether too slight to determine what part of the secondary copper ores has been concentrated from sulphides originally lying in limestone now removed by erosion. It is probable, however, that a considerable proportion is of such origin and that when the oxidized ores are worked out the copper content will decrease. It may well be, however, that in this portion of the desert region the water level is very deep.

In the rhyolite north of the east end of the copper belt are some prospects. The values reported from these are gold and these deposits are undoubtedly to be more nearly correlated with the Tertiary mineralization of the Bullfrog and certain of the Goldfield ore deposits.

Water for the district at present is hauled from the Stonewall Springs, 17 miles distant. Available wood, except the almost valueless yucca, is equally distant. However, the Cuprite mines are only 18 to 25 miles from the railroad at Goldfield, and ore may be shipped from the district at a comparatively low cost.

Lida.—Lida is situated on the western border of the area surveyed, about 34 miles south of its northwest corner. A daily stage runs from Lida to the railroad at Goldfield. The Lida mining district was organized August 28, 1871, and in the succeeding decade some rich surface pockets of horn silver and silver-bearing galena were removed. The ore, probably picked, ran from $500 to $1,000 per ton. In the latter part of 1904 and the early part of 1905, the attention of mining men having been turned to southwestern Nevada, old mines were reopened and new locations made. Unfortunately, at the time of the writer's visit in December, 1905, the principal prospects were closed through litigation and in many cases pumps and ladders had been removed.

The country rock in the vicinity of Lida consists of dark-gray limestones and olive-green shales of Cambrian age. These sediments are in the main gently folded, although locally considerably disturbed. Small faults also occur. The limestone and shales are widely and in many places most intensely injected by a granite-porphyry which may perhaps be correlated with the post-Jurassic granite intrusions. Dikes of diorite-porphyry also cut the sedimentary rocks. So far as a hasty examination showed, these masses of igneous rock are not closely connected structurally with the ore deposits. The prospects are situated partly outside the area surveyed and partly on Mount Macgruder, to the south and southeast of the village. The latter prospects alone were examined and in most cases only the dumps were accessible.

The Florida-Goldfield Mining Company's shaft is situated near the mouth of a gulch which joins the Lida Valley about one-half mile below the village. When visited, the shaft, 150 feet deep, was filled with water to within 80 feet of the surface. The ore on the dump included Cambrian limestone rather heavily impregnated with iron pyrites, pyrite inclosed in veins of coarsely crystalline white calcite, and the same ore in white quartz veinlets. In some specimens galena and light-brown zinc blende were associated with the quartz veinlets carrying pyrite. Another and apparently still more uncommon sulphide, chalcopyrite, is sometimes superficially altered to malachite and azurite. The limestone cut by the quartz veins has been more or less silicified. An old open cut above this shaft shows a zone of brecciated limestone 4 feet in width healed by innumerable connecting quartz veinlets in which the above ores occur.

On the dump of the Thanksgiving mine quartz masses and veinlets cutting similar limestone were examined. In the quartz is much pyrite and less chalcopyrite.

The Lida deposits are partially fissure fillings and partially impregnations of the country rock. The oxidized ores appear to be largely replacements of the limestone. The oxidized zone is, for a desert country, very shallow.

In the early days of mining in the district considerable bunches of oxidized ore were hauled to Austin and Belmont. It is scarcely probable that all of these pockets have been found, and, with the improved transportation facilities, such deposits should pay well. Some of the ore mined from the newly located prospects is reported to run from $100 to

$500 per ton in gold and silver values. Such assay returns, however, in at least the majority of cases, were obtained from picked samples and are of no value in estimating the economic importance of a prospect.

The water level, to judge from the development work so far carried on in the Lida district, is comparatively near the surface. Much of the ore which has already been taken out is refractory and would require milling and smelting. While in comparison with the surrounding districts the Lida district is, in these respects, at a disadvantage, there is a fair growth of piñon and juniper on the hills surrounding the mines which will furnish, for a time at least, satisfactory fuel and some mining timber. Water sufficient for mining and domestic purposes flows from springs in and above the village and can be obtained in the Lida Valley at slight depths.

Lime Point.—The name Lime Point is applied to a ridge running northwest from Slate Ridge. Recently a number of claims have been located on it and some development work is now being done. The ridge is formed of a coarse biotite granite and Cambrian sedimentary rocks. The intrusion of the granite has strongly metamorphosed the limestone and the shales have become semischists. The granite itself is cut by diorite-porphyry dikes and by pegmatite and aplitic dikes. Later flows of basaltic rocks occupy small areas.

The Bullfrog-George mine is situated on the side of a rounded, boss-like, granite hill, near the Lida-Old Camp road. The surrounding hills are cut by quartz veins which weather in relief and can be traced long distances. Some of these contain feldspar and others can be traced into pegmatite dikes. The Bullfrog-George development work is being done on a quartz vein from 4 to 9 feet wide which is traceable about a quarter of a mile. The vein is vertical and strikes N. 70° W.

The vein at some places passes gradually into the granite, the white, translucent quartz of the granite grading into that of the vein without break. Again, the granite appears to have been shattered prior to the deposition of the quartz, which now fills linked cavities in the granite. The quartz vein sometimes sends branches into the granite. Apparently isolated in the quartz are small areas of pyrite and chalcopyrite, with less galena and chalcocite or a related sulphide. The quartz in many portions is intensely crushed, this crushing perhaps being contemporaneous with the faults which cut the diorite-porphyry dikes. The crushed fragments have been recemented by limonite or a chalcedonic quartz much stained by limonite. With these knife-edges of limonite and in limonite-stained cavities malachite, cerussite, and traces of azurite occur. Such quartz pans free gold, and coarse pannings were examined from the intensely iron-stained contact of the granite and quartz. The feldspars of the granite within 4 feet of the vein are often much kaolinized. At the east end of the quartz veins less shattering was noted. Vugs lined with quartz crystals are common. Other vugs are lined with cubes of purple fluorite one-fourth inch in diameter, while finely divided flakes of molybdenite are sporadically present in the quartz.

The quartz vein itself appears to be of pegmatitic origin and to have been deposited while portions of the granite were still viscous and other portions were comparatively solid. Later faulting occurred and the quartz vein was crushed. Since then limonite and chalcedonic quartz have recemented the quartz fragments. The period at which the sulphide mineralization occurred is unknown. The molybdenite and fluorite are probably of pegmatitic origin, while the sulphides were very likely formed later.

Water is at present hauled from a pipe line on the Lida-Old Camp road 9 miles distant, while the nearest fuel is found in the vicinity of Old Camp. The camp is 30 miles from the railroad terminus at Goldfield.

Tokop.—Tokop, in an air line, is 4 miles northeast of Old Camp and 25 miles by road west of south of Goldfield. Rugged hills and rounded domes rise from the much-dissected mesa lying to the east and northeast of the settlement. The rocks present are those already mentioned as occurring at Lime Point, with the addition of dikes of granite-porphyry which, to the north of the village, cut the Cambrian and are probably to be correlated with similar dikes observed at Lida. Rhyolite flows also form a considerable proportion of the mesa already mentioned. The Cambrian shales and limestones have been profoundly metamorphosed and near the granite are schists and garnet-quartz-epidote rocks. They are complexly folded and at places faulted. The granite is pink and coarse grained. From the presence of granite dikes in the sedimentaries and from certain mining data it is assumed that the contact of the granite and limestones has a very gentle dip and that deep mines in limestone near the contact will probably encounter granite.

The properties of the Gold Crest Mining Company, situated three-fourths of a mile south of Tokop, were examined in some detail. On the Ouida claim a vertical vein cuts the garnet-quartz-epidote rock, which strikes N. 10° E. and dips 20° W. This vein is 1½ feet wide and strikes N. 80° W. The quartz is white and semitransparent. The quartz of the vein has been intensely crushed and the fragments have been cemented by hematite and limonite. Dendrites of manganese oxide also occur. Some portions of the quartz are compact, with here and there an iron-pyrite cube unaltered, while other portions have a few vugs lined with quartz crystals or are honeycombed with iron-pyrite casts. From the fact that the compact varieties are refractory and the honeycombed varieties are free milling, it is evident that the gold was set free by the alteration of the pyrite. A mashed, greasy phase of the garnet-quartz-epidote rock on one side of the vein is said to pan gold, but whether the altered pyrite originally occurred in the altered limestone or whether the values were derived from the surface alteration of the quartz veins is unknown.

Angular fragments of altered limestone and shale are common near the borders of some veins. In such instances silicification has extended into the limestone and these belts, like the quartz veins, weather in relief. Such veins grade into sheared and brecciated zones of silicified limestone and these again are reported to carry values.

Another vein is similar to that first described, but the shattered quartz is cemented by a gray chalcedonic quartz, while still another at first sight appears crustified, but close inspection shows that the appearance is due to a longitudinal fracturing of the vein and subsequent filling by limonite and the chalcedonic quartz. Both forms of quartz are said to assay, but the earlier quartz appears to carry both the sulphides already mentioned and slight amounts of galena as noted in other veins. The chalcedonic quartz may appear to carry values, because sufficient care has not been taken to eliminate the older quartz from samples.

As secondary minerals, limonite, hematite, cerussite, free gold, and a little malachite were observed. Probably some chalcopyrite exists at greater depths. One of the last changes which these ore deposits have undergone is the deposition locally of a thin film of bluish-white chalcedony.

Mr. Joseph Mackedon, the manager, states that in several prospect holes the quartz veins have passed from altered limestone to granite without diminution in size or value of content. From the striking resemblance of these veins to those of Old Camp this is to be expected.

Waters carrying silica and metallic salts in solution appear to have deposited these substances in strong fractures which extend, in some cases at least, into the granite. The country rock was to a less extent impregnated. The quartz veins were subsequently crushed and iron oxides and chalcedonic silica were deposited in the fractures. Simultaneously, probably, iron pyrite was dissolved and the gold set free.

Water and wood for mining and domestic purposes are near at hand, and the distance to the railroad at Goldfield is 25 miles.

The Rattlesnake mine, near the properties described, appears to be in the same rock formation, and its ore deposits and those of Tokop are said to be similar. Eight or ten years ago the Rattlesnake produced $150,000, and it has recently been reopened. The veins of Tokop, like those of Old Camp, seem strong, and will probably be permanent to such depths as mining is possible. With depth, however, the ore will become refractory and may become leaner.

Old Camp.—Old Camp, near Gold Mountain, is situated 30 miles west of south of Goldfield and 20 miles southeast of Lida. The almost deserted village is situated near the center of the Gold Mountain mining district, organized January 25, 1868. Mines have been worked in the district intermittently since that time and several mills have been built, none of which are now in operation. Old residents estimate the total product of the district, including Old Camp, Tokop, and Lime Point, as $500,000.

Biotite-granite, probably of post-Jurassic age, is the predominant rock in the vicinity of Old Camp. It has many facies, the prevailing type being coarse grained and pink. Areas of altered Cambrian limestones and schists are less common than in the vicinity of Tokop and Lime Point. Rhyolitic and basaltic flows of Tertiary age cap some of the neighboring hills, and such buttes are in strong contrast to the rugged granite hills.

Abandoned mines and prospects are numerous in the vicinity and a number of prospects are being developed 2 or 3 miles south of the old town. The Central mine, which supplied the ore used in the mill at Old Camp, may be taken as a type of the ore deposits in the granite of this region. This mine is situated on the side of a deep gulch 1½ miles north of east of the town. Five tunnels with an average length of 300 feet pierce the granite, and all are situated on a single vein or system of connecting veins.

The feldspar of the granite within 20 feet of the quartz zone is considerably kaolinized and the biotite is bleached or altered to a sericitic mineral. The quartz vein, or rather the zone within which the innumerable connecting quartz veinlets and stringers occur, is from 1½ to 6 feet wide. The proportional amount of quartz increases with the narrowing of the zone. The ordinary veinlets are from 2 to 5 inches wide. The silicified zone also contains many ellipsoidal and globular areas of quartz which, at least in the plane of observation, are independent masses.

The quartz zone in places changes its direction 90° within 100 feet. While minor post-mineral faults are common and fault the zone from 6 inches to 7 feet, the major changes in strike and dip are evidently original structures. The form of this zone is probably due to original lines of weakness similar to those to which the pitches and flats of the southwestern Wisconsin lead and zinc mines owe their origin.

The quartz is white and translucent or slightly smoky, with a strong vitreous luster. It contains occasional vugs with crystals up to an inch in length. In places the clear quartz seems to grade into a gray chalcedonic form, the deposition of which by water can scarcely be doubted. Isolated crystals of pyrite, with very rare crystals of chalcopyrite and galena, are embedded in the quartz. The former abundance of the pyrite in particular is shown by numerous iron-stained cavities of cubical form. Both hematite and limonite occur, and where these are abundant the gold values rise. An occasional malachite stain and a cerussite coating are present. Manganese-dioxide dendrites occur in the granite and are probably derived from the alteration of the granite rather than from a decomposing vein mineral. Horn silver is reported to be present in small amounts, but was not seen. The ore is free-milling, the arrastres, now abandoned, having saved about 75 per cent of the assay value.

Films of a bluish-white chalcedony were noted at a number of places. Some chalcedony was deposited prior to the oxidation of the pyrite, while some was deposited after partial or complete oxidation.

While the quartz is rather similar to quartz of pegmatitic origin in the district and the form of the ore deposited rather suggests that of a pegmatitic dike, the apparent gradation into chalcedony is strongly against such a view. Water appears to have filled a most complex zone of fracture with quartz and sulphides, the gold probably originally being contained in pyrite. Later oxidizing waters attacked the sulphides and altered them to oxides and carbonates, setting the gold free. These waters apparently carried some silica in solution, which was deposited as chalcedony.

The mines in the vicinity of Old Camp are situated near water sufficient for mining and milling purposes. Wood for fuel and mining timber is standing within 2 or 3 miles. The railroad terminus at Goldfield is 35 miles distant.

Oriental Wash.—Several prospects, now abandoned, are located 16 miles south of Lida, on the western border of the area surveyed. The hills in which these prospects occur are a continuation of the Gold Mountain ridge and lie south of the Oriental Wash and east of Death Valley. Here a mass of post-Jurassic biotite-granite injects a highly altered series of limestone of Cambrian or possibly of Silurian age. Contact metamorphism has developed brown garnet, epidote, quartz, and other metamorphic minerals. The granite contains numerous pyrite crystals, probably original. Rhyolitic and basaltic rocks, remnants of eroded Tertiary lava flows, also occur in the vicinity.

At one prospect a thin quartz vein cuts the limestone. Malachite, azurite, and chrysocolla, and limonite-stained chalcedonic quartz occur in irregular patches and veinlets through the quartz. Vugs occur in the secondary minerals and the azurite and malachite are often set with numerous quartz crystals. A little chalcopyrite is embedded in the oldest quartz, and cores of chalcopyrite are surrounded by the other copper minerals. A vein of malachite 1 inch in width is exposed in another prospect, apparently replacing the limestone.

The general resemblance in structural relations and mineralogic composition of these deposits to those near the granite of Oak Springs is worthy of note. The nearest water to these prospects is Sand Springs, 6 miles away. Fuel could be obtained from Gold Mountain, within 10 miles. By road the prospects are 45 miles from the railroad terminus at Goldfield.

NYE COUNTY, NEV.

Silverbow.—The village of Silverbow is situated in the canyon of Breens Creek, on the west side of the Kawich Range and about 42 miles north of east of Goldfield. The principal prospects are within 3 miles to the east, northeast, and northwest of Silverbow. The first locations were made in November, 1904. When visited by the writer (July 20, 1905), Silverbow was the supply center for several hundred men and a number of shallow prospect holes had been sunk.

The north end of the rugged Kawich Range is, with unimportant exceptions, composed of rhyolites and other siliceous eruptive rocks. The ore deposits lie in rhyolite, which in the vicinity of veins is either kaolinized to a soft chalky mass or silicified, the latter alteration being perhaps more common. The silicified rhyolite is sometimes flinty in texture and is very resistant to erosion, and in consequence forms prominent minor ridges parallel to the veins. In the kaolinized facies the feldspar phenocrysts are either kaolinized or removed in solution, while biotite, if present, is altered to a silvery micaceous mineral. Either facies may be intensely stained red, brown, or yellow by iron salts.

The more important prospects are located in parallel quartz veins or lenses which widen, thin, and often play out, forming mineralized bands whose strike in the district is in many cases north of west. The individual quartz veins vary in width from a fraction of an inch to 5 feet, and these are often connected by minor cross veins. While in many cases the quartz was deposited along pre-mineral faults, in others it occurs along joints, which sometimes form intersecting systems. Quartz likewise often fills the spaces caused by brecciation and forms in solution cavities in the rhyolite. The quartz is, as a rule, white and translucent or colorless and transparent, although in the Blazier tunnel a single vein of amethyst was noted. Crystal-lined vugs are common. Crustification is often beautifully developed, fortification-agate and mammillary forms being common.

The quartz is more or less stained by iron salts, rarely by malachite. In the quartz specks of stephanite, ruby silver, silver chloride, and probably other silver ores occur. Of these, silver chloride is certainly a secondary mineral, and to a limited extent is disseminated in the country rock. Gold occurs free. Silver is the predominant metal, and $1 in gold to $3 in silver is perhaps an average for the whole camp, although in some prospects the silver values are twenty times those of gold. The ore runs from $6 to $250 per ton, while higher values are reported. Since the writer's visit strikes in which gold predominates over silver have been reported.

In other prospects values occur in limonite stringers in the country rock, while in several prospects a greasy, crushed rhyolite carries gold values.

The striking similarity between the ore deposits of Silverbow and certain of those of Goldfield is worthy of note. Ascending water, carrying silica and metallic salts in solution, appears to have deposited its burden largely in preexisting cavities. Simultaneously waters wandering from the main channels silicified contiguous portions of the rhyolite. The kaolinization is presumably a later feature. Movement has since occurred in the veins, and they have been more or less faulted and brecciated. Surface waters have altered silver sulphides, pyrite, and probably less amounts of chalcopyrite to the corresponding chlorides, oxides, and carbonates, while secondary sulphides have also been formed. Gold, probably originally in pyrite, was simultaneously set free.

Timber and water are abundant near the mines. Goldfield is about 50 miles distant by road.

Blakes Camp.—Blakes Camp is located on one of a number of rhyolite inliers which protrude from the "wash" 12 miles northwest of Silverbow. The prospect was discovered near the end of June, 1905. A fault with well-defined walls coursing N. 80° E. cuts the rhyolite. Along this fault a zone from 18 to 24 inches wide is crushed to a fine clay in which are embedded slickensided fragments. The ground-up rhyolite is white or stained by hematite or limonite and to a less extent by manganese dioxide. This material is said to pan free gold. The rhyolite surrounding the fault is more or less silicified.

Eden.—The mining camp of Eden is situated near the mouth of Little Mill Creek Canyon, on the east side of the Kawich Range. The first locations were made February 20, 1905, by Mr. John Adams.

Three distinct vertical zones of mineralization cross Little Mill Creek from north-northeast to south-southwest, respectively one-fourth, one-half, and five-eighths mile above the old mill. The country rock is rhyolite, which in many places is intensely silicified parallel to the mineralized zones. In some cases the only indication that the material is not vein quartz is the presence of phenocrysts of slightly smoky quartz. Thin sections show fine quartz mosaics replacing both groundmass and feldspar phenocrysts. While the contact between the silicified and the unsilicified rhyolite is as a rule rather sharp, in some places there is transition. The quartz and silicified rhyolite stand out in distinct walls, aptly called by the miners "dikes," which follow the mineralized zones.

The central zone has been more developed than the others and was studied in more detail. This zone is situated along a line of faulting and brecciation, and the rhyolite near the zone is mashed. The mineralized zone varies from a vein of quartz 3 feet wide, with occasional rhyolite horses, to a band of silicified rhyolite 8 feet wide, intensely netted by quartz stringers. Parallel quartz veins more or less continuous and connected by cross veins are transitional between the two forms along the strike. The quartz, often crustified, is white and more or less iron stained. Finely divided sulphides impart a blue tinge to some of the quartz, and the parallel position in thin bands of the white and blue quartz shows clearly their contemporaneous origin. The normal crystalline quartz grades into a compact, white, flinty variety, which is said to be a good carrier of gold. Vugs usually elongated parallel to the walls of the veins are characteristic. Colorless quartz crystals are common in these vugs, while botryoidal quartz walls are less common. The vein in some portions is composed of clusters of quartz plates an inch in length set at right angles to the vein walls. This central zone is a silver bearer, the gold values being one-tenth those of silver. As silver ores, ruby and native silver are reported, intimately associated. Secondary silver chloride in knobs and wire-like masses is widely distributed in the vugs, and the silicified rhyolite itself carries values. Iron sulphide was noted in a few small specks in vein quartz.

The upper zone of mineralization is said to be very similar to the middle zone. The lower zone also is somewhat similar to the middle zone, although there is perhaps less parallelism and constancy of the quartz veins. The strike is more northerly. Pyrite locally impregnates the rhyolite. The flinty quartz already mentioned is abundant in this ledge, and the values are largely gold. The resemblance of the Eden deposits to those at Silverbow is striking, and the genesis was doubtless similar.

Water and fuel are abundant. Tonopah, the supply depot, is 70 miles distant.

Kawich.—Kawich is situated in a detrital embayment on the east side of the Kawich Range. The town is 54 miles south of east of Goldfield. The district is known as the Goldreed mining district. The first locations were made in December, 1904, and early in the spring of 1905 several hundred men rushed to the camp. When visited by the writer (August, 1905) there were about ten miners at work. Considerable development work has been done, two shafts reaching 150 feet, and several thousand feet of drifts have been driven.

The mines are situated on a gently sloping area of wash, from which numerous small, rugged outcrops of monzonite-porphyry and smooth ones of rhyolite protrude. The monzonite-porphyry is older than the rhyolite and has so far been the ore bearer. Fresh specimens of the former are gray in color, with many rather large phenocrysts of feldspar and either hornblende or biotite, or both.

The first locations were made on the property of the Goldreed Mining Company. Here a rugged outcrop of intensely silicified monzonite-porphyry, dark brown on weathered surfaces, contains in many cavities plates of hackly gold, some of which are an inch in diameter. Numerous other areas of silicified monzonite-porphyry have been located by prospectors, but at none was gold visible to the eye, although many panned gold. The silicified porphyry is light grayish brown on fresh surfaces and breaks with a conchoidal fracture. The boundary between the silicified and unsilicified portion is usually sharp. The numerous cavities are due to the removal of the monzonite-porphyry phenocrysts prior to the deposition of native gold. Strong iron stains and some dendrites of manganese dioxide are associated with the gold. The iron stains probably point to pyrite as the original source of the ore, an inference strengthened by the presence of gypsum. Quartz veinlets cut the silicified monzonite-porphyry but are said to carry no values. Certain clear phenocryst-like quartz areas indicate that silicification continued after the removal of the phenocrysts usual in the porphyry. The deepest shafts show that the silicified porphyry holds its width, although up to the time of this examination the values are low except at the surface. At the Goldreed mine good values have been obtained in a kaolinitic substance found in the cavities of the silicified monzonite-porphyry at the 100-foot level. Associated with the silicified facies are white kaolinized facies, which are often stained red or purplish by iron salts.

Iron pyrite has been encountered on the 150-foot level at the Goldreed mine disseminated in unsilicified monzonite-porphyry. Its assay value is low. Several thin veins of pyrite occur on the lower levels of the Diamond No. 2. These veins are crustified, and vugs sometimes occur in the center. This pyrite is said to assay $35 in gold per ton.

The silicified porphyry has been considerably faulted and slickensides and breccias are common. At the Goldreed mine the faulting has been very complex and certain cavities appear to be due to faulting. These cavities are wedge-shaped and reach a maximum length of 5 feet. At the Chief Kawich the faults strike N. 50° W., parallel to the silicified monzonite-porphyry boundary, and dip 80° SW. At the Diamond No. 2 the faults dip 45° E. The step-like offsets in the silicified monzonite-porphyry on which the Chief Kawich and the Goldreed mines are situated is rather suggestive of faulting, although the effect may be due to a chance distribution of several small areas of silicified porphyry.

The resemblance between the Kawich and Gold Crater deposits is close. It is probable that waters bearing silica in solution rose along joint and fault planes and that silica more or less completely replaced the rock contiguous to the fractures. Pyrite was probably deposited simultaneously, partly in the country rock and partly in open fissures. Since the silicification the veins have been faulted. The kaolinization of certain portions of the porphyry was probably contemporaneous with the surface alteration of the original sulphides. From the lean character of the pyrite so far encountered it is probable that the rich surface gold deposits have been concentrated from the pyrite contained in many feet of monzonite-porphyry, which have been removed by erosion. Other rich bodies of ore will, however, probably be encountered above the level of ground water, which is here deep.

Water is obtained at Cliff Spring, 12 miles east of the settlement, and piñon grows on the Kawich Range, 8 miles north of it. Tonopah is 70 miles distant by road.

Hills in the vicinity of Cactus Spring.—Cactus Spring is located in a group of hills lying 24 miles east of Goldfield. Rhyolite, the chief rock formation of these hills, is kaolinized or silicified in several areas near the spring. Quartz veins with many vugs cut the altered rhyolite, the quartz being coarsely crystalline and white in color. Surface outcrops are much iron stained. Pyrite and chalcopyrite are sparingly present in the quartz and somewhat impregnate the surrounding rhyolite. Both fissure filling and impregnation of the country rock have occurred. Free gold is reported from several prospects.

Wellington.—Wellington is situated in low hills 11 miles south of Cactus Spring. Claims were first located in August, 1904. When visited (July, 1905), several men were doing development work.

The country rock, a white rhyolite, is considerably altered in the vicinity of the veins, the ground mass being chalky, the biotite altered to a silvery-white hydromica, and the feldspar kaolinized. It is deeply stained by limonite. The rhyolite is apparently cut by dikes of an altered andesite or latite of purple color.

Both rocks along a zone striking N. 70° E. are cut by quartz veins, many of which strike parallel to the extension of the zone and dip northward. The larger veins are from 2 to 4 feet in width. Connecting the larger veins are numerous quartz stringers, which course in all directions, often cementing crushed areas. The semitransparent and crystalline quartz is white, although locally intensely stained by limonite. Vugs with small quartz crystals are very common, as is crustification. . Minor veins of calcite were observed. Differential movement has occurred parallel to some of the veins, and the quartz is often intensely brecciated, while minor faulting across the strike was noted in several places.

The values reported are largely gold, silver constituting but one-thirtieth of the assay value. The ore is free milling and the gold is closely connected with the limonite.

The quartz and the contained ores were deposited in joints, in the interstices of breccias, and along small and possibly large fault fissures. The veins have been faulted and the quartz crushed. Only ores oxidized by surface waters have as yet been encountered.

The railroad at Goldfield is approximately 28 miles from Wellington. Water and wood are obtained from Antelope Spring, 12 miles distant.

Trappmans Camp.—Trappmans Camp is situated 34 miles south of east of Goldfield, in low, rounded hills of granite, which is cut by pegmatite, aplite, and rhyolite dikes. Inclusions of biotite and muscovite schist are common in the granite. The veins were discovered by Messrs. Hermann Trappman and John Gabbard in June, 1904. At the time of the writer's visit, a year later, the Trappman Mining Company, of Goldfield, Nev., had five men employed in opening up the property, the chief development in July, 1905, being a shaft 50 feet deep.

The prospects are in granite, and three distinct periods of quartz formation were noted—first, quartz lenses probably of pegmatitic origin; second, quartz veins of distinctly later formation, which in one place are said to cut the rhyolite; third, quartz veins of a third generation, which cut the second. The latter class of veins is often well crustified.

The pegmatitic quartz forms bodies varying from minute stringers in the granite to lenses one-fourth of a mile long and 40 feet wide. On the contact single quartz individuals seem common to both granite and the quartz lenses. The quartz is hard and whitish, and in some places intensely brecciated and stained by limonite. It is said to carry silver and gold values.

The second class of quartz veins has sharp contacts with the granite. These veins are exceedingly common in the vicinity of Trappmans Camp, and vary widely in strike and dip. In limited areas they tend to form series of veins, often along parallel joint planes in the granite. In width the veins vary from an inch or less to a foot or more and the parallel series are sometimes a number of feet thick. These veins are sometimes faulted, as indicated by the presence of breccias, while the surrounding granite shows considerable differential movement. The quartz is slightly bluish, but is usually stained red or brown by hematite and limonite. Vugs elongated parallel to the direction of the veins are sometimes seen. On encountering the first veins, in the one instance noted, these veins are deflected downward.

The veins of the third class are of later origin than those of the second, and cut them. As a rule they are more narrow and less continuous and dip more steeply than the veins of the second class. The veins of this group often curve sharply, and the quartz in them is similar to that in the second group.

In the vicinity of the vein the granite is cut by joints stained by limonite and manganese dioxide, which are parallel to or join the quartz veins at low angles, and the surrounding partially decomposed granite is said to carry values. The granite near the veins is sometimes thickly peppered with cubes of pyrite altered to limonite.

The ore of the two younger sets of veins so far encountered is practically all oxidized, although a little original galena remains. The predominant original sulphide was pyrite, and limonite cubes after pyrite are common in the quartz. Assays show the values to be in the proportion of 1 of gold to 4 of silver. Some silver chloride was noted, while secondary native silver is reported. In one prospect calcite was noted as a gangue, with quartz.

While the quartz of one set of veins is of pegmatitic origin, its mineralization is probably later and genetically connected with the filling of the fissures of the second or possibly the third system. After the veins of the second system were fractured a second period of mineralization followed, perhaps in Tertiary time. Later the veins were crushed and surface waters have more or less completely oxidized the sulphides.

Wood and water are hauled from Antelope Springs, some 9 miles away. Trappmans Camp is 40 miles by road from Goldfield.

Wilsons Camp.—Wilsons Camp, situated on the north slope of O'Donnell Mountain, is 2 miles north of Trappmans Camp, and was discovered in May, 1904. Five miners were employed in July, 1905. At that time several shallow shafts and short tunnels were open.

The predominant country rocks are a white altered rhyolite and a biotite-andesite. Both rocks are cut by rather steeply dipping quartz veins, the majority of which strike northeast, although some strike east. The quartz veins, often crustified, are characterized by quartz-lined vugs. Since its formation the quartz has, in instances, been crushed. Limonite and less commonly malachite stains were observed on the quartz.

The reported assay values run from $110 to $180 per ton, and the average proportion is 1 of gold to 5 or 6 of silver. These quartz veins are to be correlated with the veins of Silver Bow.

The economic conditions at Wilsons Camp are similar to those at Trappmans.

Gold Crater.—The mining camp of Gold Crater is situated 10 miles east of the summit of Stonewall Mountains. Gold Crater is an inlier of older rocks, which protude in rounded hills above the basalt flow of the Ralston Mesa. These older rocks are much altered, but appear to be predominantly flows of andesite with, perhaps, more acid varieties. The first locations were made in May, 1904. In the fall of 1904 several hundred people rushed to the camp, but few remained long. At the time of visit (July 7, 1905), a number of lessees were at work.

The rocks have been in some cases strongly silicified, in others changed to a chalky mass through kaolinization. In the silicified facies the feldspar phenocrysts have often been entirely removed, while the biotite has been altered to a silvery micaceous mineral. The silicified eruptives weather into rugged crags and wall-like exposures. The country rock has been fractured, often brecciated, and in instances faulted. It is often intensely stained by limonite and hematite, especially along fractures, and from such places rich gold pannings are obtained. The ore is said to run from $40 to $240 per ton. A little chrysocolla was observed along some joints.

Waters carrying silica and metallic salts in solution appear to have ascended along faults, brecciated zones, and joints in the country rock, and there to have deposited silica, pyrite, and some copper sulphide. Later surface waters oxidized the sulphides and set the gold free. The original deposition was without much doubt an impregnation of the country rock, as is the case with the secondary minerals. There is a notable resemblance between these deposits and those of Kawich and certain of those of Goldfield.

Gold Crater is dependent for its water supply on tanks located on the basalt mesa and on two wells, respectively, 3 and 9 miles distant. Fuel for mining purposes is obtainable from the Stonewall Mountains. Goldfield is 27 miles distant.

Stonewall Mountains.—The Stonewall Mountains lie 17 miles southeast of Goldfield and are of notably symmetrical form. The predominant formation of the mountains is a rhyolite flow, which is cut by monzonite-porphyry. Quartz veins and stringers are very abundant, particularly on the north border near Stonewall Spring. These quartz veins and stringers fill faults, joints, and the cavities of brecciation, in both formations.

The most prominent vein follows a fault scarp immediately south of Stonewall Spring. The fault strikes S. 65° W. and dips 70° NW. The quartz vein is in some places simple and 40 feet wide, while in others it is complex and composed of many parallel veins. Brecciation often accompanies the faulting, the interstices between fragments of the country rock being filled with quartz. The quartz is white or colorless, rarely greenish yellow, and is beautifully crustified. Vugs with quartz crystals or mammillary quartz are common. The quartz has locally been fractured and slightly displaced, and a second quartz has filled the cavities. Heavy limonite and slight azurite stains were noted in the quartz, while pyrite is locally developed. Prospectors report traces of gold at a number of places. Timber and water are at hand in abundance.

Oak Spring.—Oak Spring is situated 50 miles northeast of Bullfrog. Here massive rounded hills of Carboniferous limestone and sandstone are injected by irregular masses of biotite-granite. The limestone near the contact is steeply tilted and has been altered to a white marble containing brown garnet, epidote, tremolite, and other metamorphic minerals. The contact facies of the granite contain rather abundant crystals of pyrite, probably of pyrogenic origin. Tertiary lavas and sediments form mesas which surround the older rocks.

In granite 1½ miles nearly due south of Oak Spring, quartz veins striking N. 30° E. and dipping 15° NW. and from 6 inches to 3 feet wide have been staked. The quartz is white and slightly sugary. Some is intensely brecciated, the cracks being stained by hematite and limonite. Vugs with small quartz crystals occur. Sulphides, sparingly present, are pyrite, chalcopyrite, galena, and zinc blende, named in the order of their abundance. From these the following secondary minerals are derived: Hematite, limonite, malachite, azurite, and cerussite. A coating of a greasy mineral in silvery tablets frosts some of the cavities. The values in this ore are said to be gold, with less silver. These deposits are similar to the second and third vein systems at Trappmans Camp.

The pegmatitic-quartz veins, abundant in a small granite mass three-fourths of a mile east of south of the spring, contain pyrite crystals, as do the less acid pegmatites and the surrounding and genetically related granite. This quartz is said to carry good gold and silver values, presumably in the pyrite.

Three hundred yards southwest of Oak Spring and down the same ridge is a 25-foot shaft in Carboniferous limestone, here locally horizontal. A vein 2 feet wide which strikes N. 35° E. and dips 70° NW., cuts the limestone. The vein is formed of malachite, chrysocolla, and a jaspery quartz which is deeply stained by blotches of manganese dioxide and limonite. Striking vugs in malachite, lined with later azurite which in turn is covered with clear quartz crystals, resemble copper-sulphate crystals. Massive yellowish-gray cerussite (lead carbonate) is also present. Post-mineral faulting has occurred. The secondary minerals, which alone are seen, partially replace the limestone and partially fill preexisting cavities.

The so-called turquoise mine at Oak Spring is a small cut in the metamorphic Carboniferous limestone 1½ miles south of the spring and three-fourths of a mile from the granite contact. Two veins strike north and south and dip 65° W., apparently parallel to the bedding of the limestone, which is here partially marmorized and silicified. The wider vein varies in width from 2 inches to 1 foot and can be traced several hundred feet. Four feet away is a parallel vein, the two being connected by a few chrysocolla stringers. The vein is composed of a mottled mosaic of chrysocolla and a dark, compact, jaspery quartz, stained in some cases by limonite and in others by manganese dioxide. The chrysocolla is usually verdigris green, although picked pieces are a beautiful robin's egg blue. The substance is usually opaque, but some is slightly translucent. The chrysocolla is commonly massive, sometimes with a botryoidal structure, and in some massive phases an occasional cleavage face is seen.

The chrysocolla is cut by managanese dioxide and white calcite or quartz veinlets. Chrysocolla veinlets of slightly different color cut one another, showing that the formation of this mineral extended over a considerable period. Associated with it is a crystalline, bottle-green, semitransparent mineral whose cleavage faces reach a length of one-half inch. A radial structure is sometimes observed. This mineral is embedded in the chrysocolla or cuts it in veins and is of contemporaneous age. It is probably brochantite, a hydrous sulphate of copper. Both the chrysocolla and brochantite, were determined by Dr. Waldemar T. Schaller. Post-mineral faults cut the veins and parallel them.

In these copper deposits the minerals exposed are all secondary. Malachite, chrysocolla, brochantite, cerussite, a jaspery quartz, and limonite seem practically contemporaneous. There is considerable evidence that the formation of the copper minerals and the jaspery quartz extended over a considerable period, during which some fracturing occurred, and in consequence the relations between these minerals are complex. They partly replace the limestone and partly fill fissures. Azurite, quartz, and calcite are of later origin.

The pieces of robin's egg blue chrysocolla closely resemble turquoise, and several hundred pounds of the mineral have been sold for this gem. The mineral takes an excellent polish. The largest piece of pure chrysocolla seen was 6 by 3 by 2 inches.

Oak Spring furnishes good water sufficient for domestic purposes and several other springs exist in the general vicinity. The Oak Spring butte is timbered to some extent. Caliente, on the San Pedro, Salt Lake and Los Angeles Railroad is the natural shipping point.

Bare Mountain.—Bare Mountain forms the east wall of the Amargosa desert, from Gold Center to a point 20 miles south. The rugged mountain ridge is intensely dissected by V-shaped canyons. The surrounding hills are composed of Tertiary rhyolitic and basaltic rocks, but the mountains themselves are formed of sedimentary rocks. Limestone is the predominant rock, probably of Ordovician age for the most part. The limestone is mostly black in color and of fine grain, although areas, particularly in the northern part, are white marble of medium grain. Interbedded with the limestones are light-colored quartzites and silvery muscovite-schists. At the north end of the range pegmatite dikes are rather common. A few intrusions of a dioritic rock are also found here. The limestone has been complexly folded and vertical dips are common. Faults frequently occur, reversed faults perhaps being more common than normal faults.

Quartz veins are common in the north end of the range and mineral locations were made on some of them early in 1905. An older set of veins, sometimes folded, is faulted by a younger set.

The Decillion claim is located in the northwestern portion of the range near the mouth of a deep canyon. The principal development work is a 50-foot shaft. Quartz veins and stringers reaching a maximum thickness of 1 foot cut limestone and schist. Some of the veins strike east and west and dip 45° S. Chalcopyrite in grains up to one-half inch in diameter is disseminated through the quartz. Malachite and a little azurite stain the quartz around the sulphide and have been deposited in cavities in the quartz. The quartz vein since its deposition has been faulted and crushed, the crushed fragments being in places cemented by granular gypsum, while gypsum crystals line some cavities. The ore of this mine is said to run high in silver, with low gold values.

The two 50-foot shafts of the Kismet Mining Company, better known as the Lonsway property, are situated on the crest of a high ridge 1½ miles southwest of Beatty. The country rock here, a quartzite, strikes N. 35° W. and dips 15° NE. The quartz vein, which is traceable several hundred feet, is from 1½ to 2 feet wide. It strikes N. 85° W. and dips 55° S.

The quartz is white or pinkish from iron stain and has a sparry texture. At the surface the quartz is deeply stained by limonite and hematite. This is said to have been locally charged with gold, probably derived from pyrite, which occurs with limonite in quartz at the bottom of the shaft. The quartzite near the vein is sheeted.

In other portions of the range galena cubes in quartz veins were noted.

The quartz and associated sulphides were deposited in open east-west fissures. Later the veins were faulted and crushed and surface waters have more or less completely altered the sulphides to oxides and carbonates, forming free milling ores.

The mines on Bare Mountain are controlled by practically the same economic conditions as are the mines of the Bullfrog mining district. Good water can be obtained in the springs of Amargosa River, one-half mile away. The most accessible wood is that of the Grapevine Range, 25 miles away. The mines are 1 to 3 miles from the proposed railroad to the Bullfrog district.

Happy Hooligan mine.—The Happy Hooligan mine is situated at the east base of the Grapevine Range, 9 miles northwest of Bullfrog. Here the major portion of the mountain range is formed of rhyolitic rocks in flows and, possibly, intrusive sheets. The rhyolite of the vicinity is pinkish or yellowish. Quartz and fewer biotite phenocrysts are still observable, while the feldspars are largely represented by numerous casts. In the vicinity of the Happy Hooligan mine are several small areas of much brecciated gray limestone, with minor quartzite beds of possibly Ordovician age. Ransome states that a tunnel driven since the writer's visit shows a thin sheet of basalt between the rhyolite and limestone. The test pits of the Happy Hooligan mine are located at the contact of this basalt flow and the limestone. At the contact the basalt is reddened by hematite and altered to a greasy substance which pans fine free gold, as does the limestone when decomposed. Gold values also occur at the contact of the basalt and the quartzite. This contact has been traced a number of hundred feet and values are reported from all test pits.

The ore is free milling and no sulphides were observed. It is said to run $40 in gold, the values appearing to be closely associated with limonite and hematite. Eventually the deposit will probably grade into a gold-bearing pyrite contact deposit.

Several springs are situated near the mine and fuel can be obtained within 6 miles. The road to Bullfrog is rather heavy.

INYO COUNTY, CAL.

Chloride Cliff.—Chloride Cliff is situated on the crest of the rugged Grapevine Range, 15 miles south of Bullfrog. The country rock is a series of early Paleozoic interbedded muscovite-schists, impure quartzites, and yellow and white limestones, all altered in varying degrees. Some lenses of a hornblende-feldspar gneiss, probably a metamorphosed igneous rock, appear to be intruded along the bedding planes of the series. These rocks are intensely folded in a complex manner and faults are common.

On the range crest, at Chloride Cliff, the limestone strikes N. 15° W. and dips 30° E. A steeply inclined fault, coursing N. 50° W., cuts the limestone. The limestone along the fault is silicified and in it are disseminated galena and some chalcopyrite. The secondary ore is a porous yellowish lead carbonate with some malachite stains. The surface outcroppings are much stained by limonite.

At another place a 4-foot vein of quartz lies between the gently dipping hornblende-gneiss and the schist and altered limestone above. The quartz is deeply iron stained and the crushed portions have been recemented by limonite. The writer traced the vein 200 feet, but it extends much farther. It is reported that one sampling across the vein gave values in gold averaging $1,500 per ton. The ore is free milling.

At a third prospect a reversed fault cuts the schist member of the series, which here strikes N. 60° W. and dips 15° NE. A quartz vein 2 to 3 feet wide occupies the fissure. The quartz is stained by limonite and the only original sulphide seen is pyrite. Small nodules of native copper are rarely associated with the limonite stains. The ore is said to assay from $13 to $500 per ton in free gold. The values are associated with limonite.

The prospects at Chloride Cliff are on either fissure veins or contact deposits. In some cases the quartz and accompanying sulphides probably filled open fissures, while in others the limestone was metasomatically replaced. There is a distinct tendency for galena to be the predominant sulphide in limestone and pyrite in the other country rocks. Since the deposition of the quartz the veins have been crushed and surface waters have produced from the original sulphides native gold, copper, cerussite, malachite, and limonite. The deposits are structurally those which hold their values well with depth, and if surface enrichment has not been out of all proportion to the original sulphide values further development is well justified.

Water is at present packed on burros from Keane Spring, 4 miles distant. Wood suitable for fuel occurs on the Grapevine Range 10 miles north of the prospects, but at present must be teamed by way of Bullfrog. A fair road connects the prospects with Bullfrog, the shipping and supply point.

Gold Belt.—Gold Belt, a deserted camp in the Panamint Range, is situated in a deep gulch near the southwest corner of the area surveyed. Here the black, fine-grained Silurian limestones are injected by a batholith of diorite, in which both hornblende and biotite are usually associated. The limestone has been altered near the contact to a white coarse-grained marble. A number of men are said to have rushed to this camp in the spring of 1905, but little work was accomplished. The more important development work was done on certain thin veins or lenses in the diorite. The ore contains a little chalcopyrite, probably a portion of the original sulphide unaltered. Of clearly later origin are chrysocolla, malachite, and a dark-brown or black iron-stained chalcedony of approximately contemporaneous age. These minerals are coated with small quartz crystals. This ore is said to pan free gold. Similar ore is reported from other localities in this diorite area. A specimen from near the headwaters of Cottonwood Creek is identical with the ore of Oak Spring already described, both chrysocolla and brochantite being present.

Water and fuel are near by. Gold Belt is 50 miles from Bullfrog by trail and road.

A RECONNAISSANCE OF THE MINERAL DEPOSITS OF NEW MEXICO.

By Waldemar Lindgren and L. C. Graton.

INTRODUCTION.

A general reconnaissance of the mineral deposits of New Mexico was undertaken during the field season of 1905. The two principal objects in view were, first, to obtain, for practical purposes, a needed summary of the condition of the mining industry throughout the Territory, and, second, to develop general conclusions bearing on the origin of the deposits. It was held that such a reconnaissance would bring out the salient facts relating to genesis better than a detailed examination of one or two of the larger districts. In addition, it was expected that the work would disclose much of interest and value regarding the general geology and serve as a basis for a preliminary geological map of the Territory.

Dr. C. H. Gordon, of Socorro, N. Mex., examined the deposits of Sierra, Socorro, and part of Luna counties. Many statements based on his work will be found in the following pages. Mr. F. C. Schrader, of the United States Geological Survey, examined a number of copper deposits in the northwestern part of the State.

A summary of the facts ascertained and some of the conclusions drawn from them are contained in this article, which is simply a preliminary statement, possibly to be modified by the more detailed study of collections and notes now in progress.

GENERAL GEOLOGY.

PHYSIOGRAPHIC PROVINCES.

New Mexico is divisible into four more or less distinct regions or provinces, the division being based on the character of the surface of the country.

The northwestern portion of the Territory is a diversified plateau region which, extending across northeastern Arizona and southwestern Colorado into Utah, forms part of the Great Interior Plateau of the western United States. This plateau has been considerably modified by recent erosion, but presents in broad view a fairly flat expanse of large extent.

To the south of the great plateau and separated from it by a somewhat indistinct boundary is the region of desert ranges. This province occupies nearly the whole of the southwestern quarter of New Mexico. It extends southward into Mexico and, sweeping diagonally across central Arizona, connects with the Basin Ranges of Utah and Nevada. This province is characterized by broad Quaternary desert plains, through which protrude isolated knobs, clusters of peaks, and comparatively short ranges. The latter extend in generally parallel north-south directions, but they can not be correlated into any system.

Bounding the great plateau and the desert-range province on the east the central mountain belt extends along the middle of New Mexico and is one of the most important physiographic features of the Territory. To the south it is represented by ranges along the Rio Grande in Texas and Mexico and to the north it merges into the Sangre de Cristo Range of Colorado, and thus constitutes the southerly extension of the Rocky Mountains. The main drainage line of the region, the Rio Grande, which traverses the entire Territory from north to south, lies along the west side of this mountain belt. From the Colorado line to a little south of Santa Fe this mountain province is conspicuous and distinct, comprising the lofty Mora, Taos, and Santa Fe groups or ranges. Farther south the province is represented by three chains of disconnected ranges which nevertheless conform in trend to the more prominent ranges to the north. On the east are the Jicarilla Mountains, the Sierra Blanca, and the Sacramento and Guadalupe Mountains. The central and best-defined chain is made up of the Sandia, Manzano, Oscura, San Andreas, Organ, and Franklin ranges, to which may be added the group of laccolithic mountains known as the Cerrillos, the Ortiz, San Pedro, and South mountains. On the west are the Ladrone, Limitar, Magdalena, Fra Cristobal, and Caballos mountains. These ranges, which comprise the southern part of the central mountain province, have few features, individually, to distinguish them from many of the desert ranges except in their position as parts of a linear chain of such ranges. There exists, apparently, a transition from the central mountain province to the desert-range province.

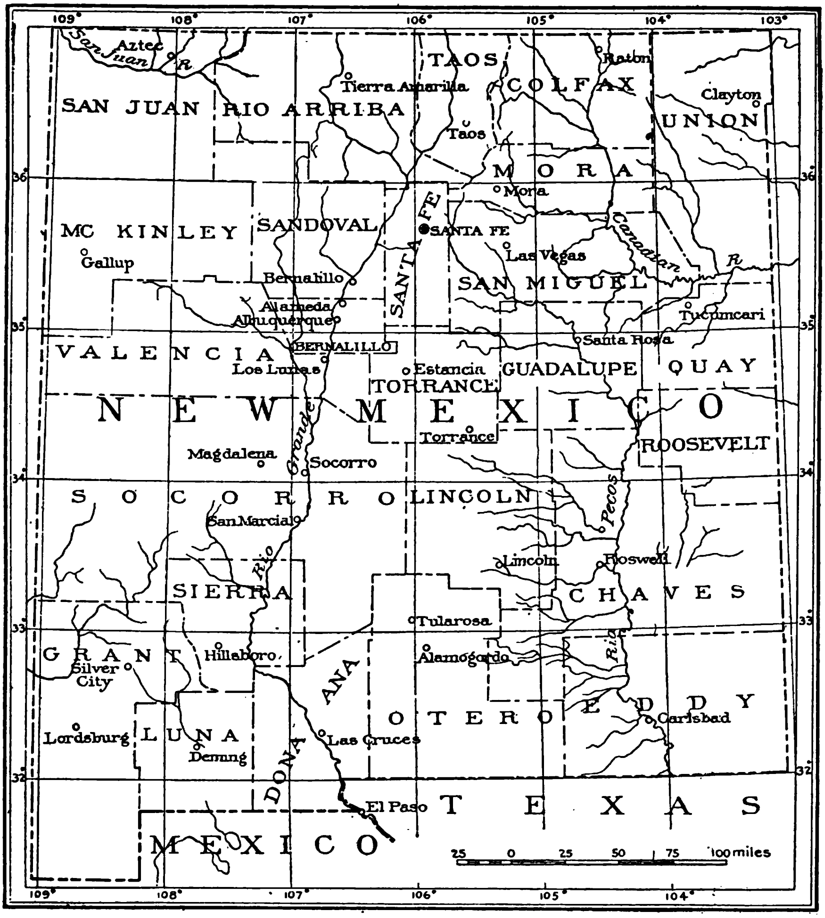

FIG. 4.—Map of New Mexico.

East of the central mountain belt the foothills merge into the broad, gentle slopes which form a part of the Central Great Plains of the United States.

THE ROCKS.

The geological features of New Mexico are extremely varied. Beginning with the old pre-Cambrian basement, which here, as to the north, constitutes the cordilleran protaxis of the continent, rocks of almost every period up to the most recent deposits are known somewhere in the Territory. The three great divisions of rocks—igneous, sedimentary, and metamorphic—are abundantly represented.

PRE-CAMBRIAN COMPLEX.

The northern half of the central mountain belt is composed largely of ancient crystalline rocks which can without hesitation be assigned to pre-Cambrian time. The cores of most of the ranges which constitute the southern part of this belt, such as the Sandia, Magdalena, Caballos, and Franklin mountains, are likewise composed of these rocks, as are also some of the ridges in the desert-range province—for example, the Burro Mountains. Red and gray gneisses, which represent sheared granites, are most abundant, although many of these rocks are only a little foliated, and much massive granite is present. Dikes and other intrusive bodies of diorite, gabbro, diabase, etc., have in most cases suffered sufficient shearing and mineral alteration to be converted into dark schistose rocks, which may be grouped together as amphibolite. Extreme foliation of the granitic gneisses frequently results in the production of quartz-sericite schists, and less commonly quartz-biotite schists. Some sedimentary rocks, such as quartz-pebble conglomerates, sandstones, shales, and limestones, also enter into the pre-Cambrian complex and have been metamorphosed more or less completely into schists.

Dikes of pegmatite and aplite cut many of these foliated rocks, but are themselves pre-Cambrian.

SEDIMENTARY ROCKS.

On the basement of old crystalline rocks thick sediments of Paleozoic, Mesozoic, and Cenozoic age have been deposited and have suffered little or nothing from the effects of regional metamorphism. In the north half of the Territory, where the ancient crystalline rocks are overlain by sediments, the Carboniferous strata rest unconformably upon the pre-Cambrian. The most widely distributed sedimentary formations are, therefore, Carboniferous or younger, and the older Paleozoic strata have generally been considered absent, although Cambrian [a] and Silurian [b] have been reported. Representatives of each age from Cambrian to Tertiary, inclusive, are now known to be present,[c] and in the southwestern part of New Mexico Cambrian, Ordovician, Silurian, and Devonian strata separate the Carboniferous beds from the pre-Cambrian. In general these strata succeed each other without apparent unconformity from the beginning of deposition of sediments to the period of eruption at the close of the Cretaceous system. The geological section is by no means complete, however, and in some cases actual unconformities have been observed. These will be mentioned specifically under structure.

Quartzites, often of dark color because of iron stain, containing thin bands of sandy shale and siliceous limestone, are found resting upon the pre-Cambrian gneisses in numerous places in the southwestern part of the Territory. This formation ranges in thickness at various places from about 100 feet to over 1,000. In a shaly layer from the Caballos Mountains Doctor Gordon has found *Lingulella* shells, which unquestionably define this quartzite horizon as Cambrian.

Overlying the Cambrian quartzite without break are 600 to 1,000 feet of limestone, very cherty in the lower half and often much silicified. Fossil fragments suggest that the lower part may be Cambro-Ordovician, while good specimens from higher horizons are certainly Ordovician. This formation has been found in the Caballos and Florida mountains, at Kingston, Hillsboro, Cooks Peak, Silver City, and probably occurs in the Georgetown mining district.

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[a] Yung and McCaffery, Trans. Am. Inst. Min. Eng., vol. 33, 1903, p. 354.
[b] Clark, Ellis, Trans. Am. Inst. Min. Eng., vol. 24, 1894, pp. 138-167.
[c] Cf. Gordon and Graton, Am. Jour. Sci. May, 1906.

In the section west of Silver City the Ordovician limestones are overlain by 200 or 300 feet of limestone which is conformable and similar to those below, but which contains a fauna that is referred by Ulrich to the Silurian. The upper portion of this limestone is the ore-bearing horizon which has been explored by the mines of Chloride Flat. It may be that Silurian rocks are more widely distributed in this part of New Mexico than is at present known.

Black fissile shales of Devonian age overlie the Silurian and Ordovician limestones. In general no stratigraphic break is observable, but Doctor Gordon is of the opinion that there is an unconformity between the Devonian and the underlying rocks at Hillsboro. About 200 feet of these black shales are succeeded in some places by about an equal thickness of red shales, all of Devonian age.

Mississippian (Lower Carboniferous) strata have been found only in the southwestern part of the Territory where the older Paleozoic formations are present. They consist of some 350 to 500 feet of bluish, mostly fine-grained limestone. Where Pennsylvanian rocks overlie the Mississippian they also are mostly crystalline limestones and attain a thickness of several hundred feet. Where the Pennsylvanian beds rest directly on the pre-Cambrian rocks, as is the case in the northern ranges, they consist at the bottom of red conglomeratic arkose or grits resembling granite in appearance and representing rapid erosion and deposition. The upper portions are of crystalline limestone, with occasional thin beds of shales. Beds of coal of promising quality and sufficient thickness to allow mining have been developed to a small extent in these shales along upper Pecos River. This is one of the few known instances of Carboniferous coal in the West. In the northern part of New Mexico these strata are 1,000 feet thick at least and probably considerably more. Much of the "red beds" in the southern and southeastern part of New Mexico, hitherto described as Permian, is probably of Pennsylvanian age; but in the Guadalupe Mountains, according to Girty, occurs a series of rocks which may represent the Permian, and a few imperfect fossils collected at Lone Mountain near Silver City are said by Girty to suggest a "Permo-Carboniferous" horizon, although faulting and igneous intrusions make the stratigraphy uncertain.

The greater part of the red sandstones and shales which cover the Pennsylvanian limestone in the northern half of the Territory have generally been referred to the Jurassic and Triassic systems, although little or no proof is known that they belong there. The lower strata are coarser and more thickly bedded, while the upper portion is generally composed of rather thinly bedded fine-grained sandstones and shales. Some of the beds are gypsiferous. An interesting feature in regard to these "red beds" is the fact, evidenced in a number of places, that they were originally drab or olive-colored rocks and that, contrary to the general belief, their red color has been developed by oxidation since their deposition and consolidation. Yellowish and olive sandstones overlying Pennsylvanian limestones in the southwestern part of New Mexico may also belong here. Step faulting has been prominent in most places where these rocks were observed and makes difficult any estimate of their thickness.

In the northern and eastern parts of New Mexico Cretaceous beds have long been known. Sandstones and shales, belonging, respectively, to the Dakota and Colorado formations, are overlain by the coal measures which are supposed to be of Laramie or Fox Hills age. In the southwestern part of the Territory, Cretaceous rocks have not heretofore been known, but in dark shales some hundreds of feet thick occurring just west of Silver City, fossils have been found which have been identified by Stanton as within the Benton group of the Cretaceous. Similar beds were found farther to the northwest, and all of them are probably of the same horizon as those described from the Clifton quadrangle, Arizona.[a]

Partially consolidated gravels, sands, and marls occur as wash plains and immense alluvial fans at the foot of the higher elevations. Some Tertiary fossils have been found in these beds in the vicinity of Santa Fe, and most of such deposits are accordingly referred to the Tertiary system, while some probably belong to the Quaternary.

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[a] Lindgren, W., Geologic Atlas U. S., folio 129, U. S. Geol. Survey, 1905, p. 5.

IGNEOUS ROCKS.

Much massive granite occurs in the pre-Cambrian areas and has therefore already been mentioned. Igneous rocks of post-Paleozoic age are also abundant and in many cases are important because of their intimate connection with ore deposits. There are two distinct groups of these younger igneous rocks—the intrusives and the effusives—although in certain cases intrusive bodies of rocks which otherwise occur principally as flows are known.

The intrusives comprise granite and porphyries. Granite known to be younger than Carboniferous has been found by J. B. Richardson in the Franklin Mountains, where it occurs along faults. In the Organ Mountains a granite cuts Carboniferous strata and at its periphery is decidedly porphyritic. There is no proof that these granites are post-Cretaceous and the fact that pre-Cretaceous, post-Carboniferous granite occurs in the Bisbee [a] district is significant in this connection. On the whole, however, it seems more likely that the Organ Mountains granite at least corresponds in age with the porphyritic intrusives and is post-Cretaceous.

The porphyries in almost all localities are closely related in appearance, being light-gray rocks with prominent white phenocrysts of feldspar. They range in composition from granite-porphyry through syenite-porphyry, quartz-monzonite-porphyry, and monzonite-porphyry to diorite-porphyry. Intermediate types are by far the most common. What may be considered the representative of these porphyries is practically the same rock that occurs in the Clifton copper district. These rocks are of post-Cretaceous age. Important masses of them occur near Red River; at Elizabethtown; in the Cerillos, Ortiz, and San Pedro mountains; at Magdalena, Santa Rita, Hillsboro, and Hanover; and in the Burro Mountains, the Jarilla Mountains, and the Sierra Blanca.

The flow rocks, which are the youngest igneous rocks of the region and cover almost all other deposits, comprise rhyolites, andesites, dacites, and basalts. The rhyolites and dacites are probably most abundant and in places attain a thickness of over 1,000 feet. These rocks, which sometimes contain thin interbedded flows of basalt, are supposed to be of middle Tertiary age. The latest lavas consist of sheets of basalt and are widely distributed throughout the territory. Some of these flows are so recent that the surface is practically unaffected by decomposition or erosion and presents the characteristic broken and ropy appearance of very young lavas.

The older flows are mainly confined to a broad tongue piercing the middle of the Territory from the west as far east as the Rio Grande, although rhyolite is also known in the vicinity of Red River. The younger basalts occur in many places over the northwestern quarter of New Mexico, in various localities east of the central mountain belt, and along the Mexican boundary line west of El Paso.

STRUCTURE.

Of the four factors which have produced the present topography of New Mexico—effusion of lavas, sedimentation, crustal movements, and erosion—the first three appear at first sight to have been by far the most important, while erosion seems to have simply modified the details of their broad effects. But more careful consideration indicates that only by extensive erosion have the effects of crustal movements been exposed and that erosion has prepared the place for sedimentation and surface flows. Erosion therefore is of paramount importance.

Deposition of sedimentary rocks is responsible for the broadest physiographic features of the plateau province and the great plains and the level portions of the desert-range region. Lava flows have in most cases simply veneered over the surface of these plains of sedimentation, but in some instances have mantled and leveled surfaces of erosion.

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[a] Prof. Paper U. S. Geol. Survey No. 21, 1904, Pl. XII.

Next to erosion in striking results undoubtedly come movements of the earth's crust. Folding in the strict sense has gone on only to a slight extent in New Mexico, but faulting and doming are exceedingly important.

The Rocky Mountain core is generally believed to have been a land area from pre-Cambrian to near the close of Paleozoic time. This view is sustained in the northern part of New Mexico by the absence of Paleozoic sediments older than the Pennsylvanian series of the Carboniferous. In he southwestern part, however, the sea was present more or less continuously from the beginning of Cambrian time on. At the end of the Lower Carboniferous the northern land area was submerged and sedimentation went on throughout the Territory, possibly with some interruptions, till the close of Cretaceous time. By this time practically the whole Territory was covered by a thick mantle of Cretaceous sediments. Then followed the great crustal movements which left their impress on the present topography. These movements were of two kinds. One was an upthrust of pre-Cambrian rocks along north-south lines, producing longitudinal faulting and bending up the strata on the sides of the ridges so produced. Step faulting with repetition of the strata was a very common result. These phenomena are well shown along both sides of the mountain belt from Santa Fe northward, especially along the upper Pecos and northwest of Las Vegas. Faults undoubtedly bound the steep sides of the Sandia, Manzano, Oscura, San Andreas, Organ, and Franklin mountains. The other movement was brought about by the porphyry intrusions, which formed stocks with some doming of the strata in the Paleozoic sediments and true laccoliths with very decided doming in the Cretaceous sediments. Erosion has since carried away the upper portion of these domes, leaving the igneous rocks exposed. Many instances might be cited. The Cerrillos, Ortiz, and San Pedro mountains are clearly defined laccoliths, while sediments domed by intrusive masses occur in the White Oaks, Elizabethtown, Pinos Altos, and other districts. No local movements of orogenic importance appear to have taken place since these post-Cretaceous movements, for the Tertiary sediments and flows remain practically undisturbed, but a general Tertiary uplift is indicated by the present elevation of the country.

ORE DEPOSITS.

GENERAL FEATURES OF THE MINING INDUSTRY.

New Mexico does not rank very high among the metal-producing States of the West. According to the last report of the United States Geological Survey,[a] the total value of gold, silver, copper, lead, and zinc produced in 1904 amounted to only $2,186,287. On the other hand, the output of coal alone in the same year was about 1,500,000 tons, of a value of $1,900,000. The Territory yielded only $381,930 in gold, of which $149,424 was taken from placer mines. Most of this placer gold came from Colfax County, near the northern boundary line, and from the new diggings in Apache Canyon, in the south-central part of Sierra County. Lode mining of gold ores was carried on chiefly in the Mogollon district and the Rosedale mine in Socorro County, in the Hillsboro district in Sierra County, and in the Silver City district in Grant County, all in the central or southwestern part of the Territory. The silver ores yielded a value of $124,103, the Mogollon district in Socorro County and the Silver City mines in Grant County leading, while Sierra, Luna, and Dona Ana counties contributed smaller amounts.

The copper produced in the Territory had a value of $646,382, the old mines of Santa Rita and the recently developed deposits in the Burro Mountains, both in Grant County, contributing the largest share; Socorro County added an amount of copper valued at $55,316 from the Mogollon district. Lesser amounts came from the Organ Mountains in Dona Ana County and from San Miguel County.

The value of the lead was $134,283, of which the largest part came from the mines in the Organ Mountains in Dona Ana County; smaller amounts were derived from the Cooks

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[a] Jones, F. A., Mineral Resources, U. S., for 1904, U. S. Geol. Survey, 1905, pp. 200-203.

Peak mines in Luna County, from the Granite Gap mine and others in Grant County, and from the Magdalena mines in Socorro County. The mining of zinc ores has become an important industry in the Magdalena district of Socorro County and promises to become so in the Tres Hermanas district in Luna County. The metal produced in 1904 is reported as having a value of $899,589, a considerably larger amount than is represented by the silver, gold, copper, or lead industry.

GEOGRAPHIC DISTRIBUTION OF DEPOSITS.

The Great Plains and the Plateau Province of eastern and northwestern New Mexico do not contain metalliferous deposits except local iron and copper ores distributed in sedimentary rocks. On the other hand, the metallic ores are present in every mountain range in the Territory. They occur in the continuation of the Rocky Mountain system in northern New Mexico, in the Zuñi uplift, in the Sandia, Magdalena, San Pedro, Manzano, San Andreas, Oscura, Organ, Mimbres, and almost all of the small desert ranges of southwestern New Mexico. They also occur in the broken-down edge of the Plateau Province about Silver City and in several of the large rhyolite fields in the southwestern part, extending from the Mogollon Mountains into Socorro County.

By far the majority of metalliferous deposits are found in the southwestern quarter of the Territory, and in this area most of the important deposits extend in a curved line from Socorro through Hermosa, Chloride, Kingston, Hillsboro, Lake Valley, Cooks Peak, Santa Rita, and Pinos Altos to Silver City and the Mogollon Mountains near the Arizona line.

There is little indication of any regularity in the geographic distribution of the different metals within the metal-bearing region.

GEOLOGICAL DISTRIBUTION OF DEPOSITS.

Almost every known type of deposit is found in New Mexico. There are ores of copper and iron contained in sedimentary beds; normal, sharply-defined fissure veins, carrying gold, silver, lead, copper, or zinc; wide shear zones, stringer leads, and lenticular bodies of ores, both in intrusive rocks and in the old pre-Cambrian schists; irregular replacement deposits, usually in Ordovician, Silurian, or Carboniferous limestone; irregular-contact deposits, containing copper, lead, and zinc, but usually poor in gold and silver, along the boundaries between intrusive rocks and limestones of any age; and finally gold-bearing gravel beds of Tertiary or recent age.

In a general way the pre-Cambrian schists contain fahlbands, shear zones, and veins of copper and zinc sulphides, low in gold and silver; the Paleozoic limestones are apt to harbor the irregular copper, lead, and zinc deposits, often greatly enriched by processes of oxidation and in places containing much silver; the intrusive porphyries and granites contain fissure veins with gold, silver, or both, and (in most cases) minor amounts of the base metals; and, finally, the flows of rhyolite and andesite inclose, at some places, fissure veins rich in gold and silver, but commonly with relatively small amounts of copper, lead, and zinc.

AGE OF THE DEPOSITS.

In the gold placers, as well as in some of the bedded iron and copper deposits, the valuable metals were introduced or laid down at the same time as the accompanying rock was formed. These deposits are often called syngenetic. The important ore bodies of the majority of New Mexico mines belong to the class of epigenetic deposits, in which the metals were introduced at a time when the surrounding rocks had already been formed. During the present reconnaissance particular attention was given to the question of age, in the hope of discerning the main epochs of ore formation. The results have justified this and it has been shown that certain physical characteristics of the deposits in general distinguish these several epochs, even if the criteria are not always sufficent to determine age in the absence of general geological evidence.

Two principal ages of ore formation have been recognized. The older is pre-Cambrian, while the younger or post-Cretaceous age includes two periods—one late Cretaceous or early Tertiary, and another extending from middle Tertiary practically to the present time.

PRE-CAMBRIAN DEPOSITS.

It is generally admitted that the principal period of ore formation in the Cordilleran region falls within age limits ranging from Jurassic to late Tertiary. That this was preceded by an earlier period is definitely shown in the Black Hills of South Dakota, where Cambrian conglomerates with detrital gold overlie auriferous stringer leads and shear zones in pre-Cambrian schists. It has long been suspected that some Wyoming deposits[a] belong to the same period and according to a recent report by Spencer[b] some of the copper deposits in the Encampment region in Wyoming are surely of pre-Cambrian age, while others, including the principal productive mine, were most probably also formed in that period. The recognition of pre-Cambrian ores in New Mexico justifies the inference that the pre-Cambrian complex of Colorado may contain similar ores, and it is probable that a reconnaissance of Colorado would soon elucidate this question.

As elsewhere in the Rocky Mountain region, a profound unconformity separates the little-altered series of Paleozoic sediments beginning with the Cambrian from a pre-Cambrian complex of granites, gneisses, and various crystalline schists. In northern New Mexico the Carboniferous rests directly upon these oldest rocks, but the Cambrian is present in the southern part of the Territory, as it is in Colorado. There can be no error or misunderstanding in referring to the deposits in question as pre-Cambrian.

The first definite proof of the existence of these old deposits was found at the Hamilton mine on the upper Pecos, 20 miles east of Santa Fe. The deposit contains chalcopyrite and zinc blende and is inclosed in a somewhat schistose amphibolite. Its weathered outcrop is directly and unconformably overlain by nearly horizontal Carboniferous sandstones and limestones. The weathering, which does not extend to a great depth, was certainly effected before the deposition of the covering of the sedimentary rocks.

Many similar deposits occur in the pre-Cambrian of the Santa Fe Range all along up toward the Colorado line. At one of them, situated north of Taos, development work on a large scale has been attempted by the Frazer Mountain Copper Company, and during 1903 a considerable amount of copper, containing some gold and silver, was produced. The evidence of age is not as conclusive in the latter case as it is at the Hamilton mine, but it is very strong.

In the Hopewell and Bromide districts, in Rio Arriba County, narrow stringer veins in altered amphibolite carry copper, gold, and in some places silver, both in the quartz gangue and in the adjoining wall rock. The proof that these deposits are pre-Cambrian is not wholly conclusive.

The pre-Cambrian deposits contain chiefly pyrite, chalcopyrite, and zinc blende; the country rock is usually an amphibolitic or chloritic schist derived from old basic intrusions into the prevailing granites and gneisses; the tenor of gold and silver is ordinarily low—say $3 in gold and 3 ounces of silver. Several types may be distinguished among them: In one the sulphides occur intergrown with the hornblende or other minerals of the containing amphibolite or gneiss and appear to have been formed during the metamorphism of the rocks. In another the ores are contained in more or less irregular or lenticular veins in the schists; quartz is the gangue, sometimes accompanied by tourmaline or garnet. In still another type the copper ores, accompanied by lenticular streaks of quartz and siderite, appear along chloritic shear zones in amphibolitic rocks.

These types strongly recall the description of the Encampment, Wyo., deposits given by Spencer,[c] and in their general appearance they also resemble those upon which the gold and copper mines of the Southern Appalachian States are working.

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[a] In the Silver Crown and Sweetwater districts. See Lindgren, W., The gold production of North America: Trans. Am. Inst. Min. Eng., vol. 33, p. 839.

[b] Spencer, A. C., Prof. Paper U. S. Geol. Survey, No. 25, 1904, p. 56.

[c] Op. cit., p. 53.

Economically they are not very important and have contributed but little to the metal production of the Territory, though some low-grade bodies may be developed into important mines. Placer deposits are connected with some of them, but they are rarely rich.

POST-CRETACEOUS DEPOSITS.

Almost the entire metal production is obtained from deposits of post-Carboniferous age. It is possible that some of these are late Mesozoic, but all of them concerning which we have definite knowledge are later than the Benton (Cretaceous) and range in age almost up to the present time. Without fear of serious error they may be referred to as post-Cretaceous. One of the most positive results of this reconnaissance consists in the accumulated evidence of their geographical and genetical connection with the great igneous activity which manifested itself in this Territory from the earlier part of the Tertiary up to a recent date.

The deposits are divided into two distinct series. The first and earlier is directly connected with great intrusive bodies of acidic porphyries and granitic rocks, and consists of contact-metamorphic deposits, fissure veins, and replacement deposits in limestone. The second and later is connected with the floods of lavas which overwhelmed many areas of this Territory, and consists of fissure veins, probably also replacement deposits in limestone.

EARLIER SERIES.

The deposits connected with the intrusive rocks have thus been separated from those which are in some way allied to the surface flows. It is recognized that in some districts, like southwestern Colorado, erosion has exposed the plutonic rocks which were intruded at lower levels at the time of the effusion of the lavas at the surface. In New Mexico there is no evidence of such deep trenching of the Tertiary lavas.

The intrusive stocks of porphyries and granites are distinctly older than the surface flows and their irruption took place when probably the whole of New Mexico was covered by thick horizontal Cretaceous sediments, forming a pliable and plastic sheet, underneath which the conditions were present for the formation of laccoliths and stocks. Whether the magma broke through this covering or not is not known. A long-continued erosion in many places exposed these intrusives and after this had been done renewed igneous activity followed and surface lavas—andesites, rhyolites, and basalts—covered large areas. The writers would refer the earlier epoch of intrusion to the early Tertiary and the latter epoch of effusion to the middle or late Tertiary.

A review of the deposits of early Tertiary age involves a mention of all the important intrusive stocks of the Territory.

To begin from the north, Colfax County contains a stock of syenitic or granite porphyry, intruded in upper Cretaceous and earlier terranes. Contact-metamorphic deposits mark its periphery at certain places, probably where the Colorado shales are especially calcareous. Garnet, epidote, hematite, and magnetite are the gangue minerals and are accompanied by small amounts of chalcopyrite and in some cases by good values in gold. The same phenomena are repeated in the Cimarroncito district a few miles to the south, where copper is the predominant metal. The igneous rock, as well as the Cretaceous rocks adjoining, are cut by a great number of small auriferous veins, which, though not often workable, have enriched with placer gold practically all the branches of the Cimarron which head in this area.

At Cerrillos, in Santa Fe County, similar intrusive rocks form a smaller stock in upper Cretaceous or Laramie rocks, the sandstone and shale of which have proved less suitable for contact metamorphism. The stock is traversed by a number of northeast veins which carry zinc blende and argentiferous galena and in places extend for some little distance out into the sedimentary rocks.

The Ortiz and San Pedro mountains are small isolated groups a short distance south of Cerrillos and also in Santa Fe County. Both form laccolithic intrusions in Cretaceous and older rocks. Along the contact of the porphyry with the shales baking and contact metamorphism is observed. Along the south contact of the Ortiz Mountains, where calcareous Cretaceous strata adjoin the porphyry, low-grade contact-metamorphic deposits occur, with garnet and chalcopyrite, the latter carrying a little gold. A system of narrow auriferous quartz veins, on one of which the celebrated Ortiz mine was worked, intersects the porphyry of the Ortiz Mountains and has yielded rich placer deposits. The San Pedro laccolith has produced contact-metamorphic copper deposits with economically important ore bodies of chalcopyrite, accompanied by garnet gangue, in Carboniferous limestone. Here again a system of small but rich fissure veins intersects the laccolith and even extends for a short distance into the sedimentary rocks.

At Jarilla, Otero County, a laccolithic mass of porphyry has bulged up the Carboniferous limestones and in certain strata has produced contact deposits carrying gold values, with garnet, epidote, and hematite gangue. In the porphyry and extending out into the sedimentary rocks are quartz veins, some of which carry principally gold and some gold and copper. Erosion of these veinlets has formed the well-known placers at the eastern foot of the hills.

The conspicuous Organ Range in Donna Ana County, east of Las Cruces, is continued southward into the Franklin Range and northward into the San Andreas Range. The Organ Range consists chiefly of granite with associated porphyries, and this granite has been regarded as pre-Cambrian by several writers. This is erroneous, though it is possible that the pre-Cambrian complex may be present in some parts of the range. The granite forms a large laccolithic stock intrusive into Carboniferous limestone and probably continues northward into the little-explored San Andreas Range. For a distance of several miles the limestone is contact metamorphosed, with the development of garnet and payable bodies of now partly oxidized chalcopyrite. Deposits of lead and zinc ores occur short distances away from the contact in the limestone. The granite is traversed by a system of east-west fractures, which contain quartz with gold or silver bearing sulphides.

The small but conspicuous mountain group of Tres Hermanas rises near the Mexican boundary in the southern part of Luna County. In the northerly foothills lead and zinc deposits associated with garnet and wollastonite and of typical contact-metamorphic character have been formed where granite adjoins the Carboniferous limestone. Until recently only lead ores were mined at Tres Hermanas, but lately large quantities of oxidized zinc ores have been discovered. Here again the granite contains a number of narrow quartz veins with silver-bearing lead ores.

Near Hachita, in southern Grant County, the low Apache Hills show irregular intrusions of monzonitic porphyries through Paleozoic limestone. Contact metamorphism with garnet and chalcopyrite is in evidence along the boundary line of the formations, and from one of the deposits, called the Apache mine, oxidized copper ores are shipped, which occur in an extremely coarsely crystalline limestone.

The Hachita Range consists of folded and faulted Carboniferous and probably Cretaceous strata (Comanche formation), with a network of porphyry dikes and sills. Limestone and dikes are cut by a system of northeasterly trending fissure veins which contain galena and zinc blende. In at least one place, "The Copper Dick" mine, where payable copper ores are found, the Cretaceous limestone has been converted into garnet and chalcopyrite.

A large laccolithic mass of porphyry domes up the strata at Santa Rita, Hanover, and Fierro, in Grant County. At the two latter places limestones in contact with the intrusive rock have been metamorphosed and contain low-grade deposits of chalcopyrite, in places with considerable amounts of zinc blende. Garnet, epidote, and magnetite are abundant gangue minerals. Throughout the district ore-bearing fissures occur, principally in the porphyry. In these gold values are generally low, but copper and sometimes lead and zinc are more important. Where little quartz is present and the veins consist principally of narrow streaks of sulphides, secondary enrichment has doubtless played an important part in the formation of ore of workable grade.

Narrow veinlets carrying cupriferous pyrite in porphyry occur in the Burro Mountains. Concentration by descending waters has here likewise probably induced the formation of disseminated chalcocite and has raised the ore to its present grade.

At Pinos Altos, north of Silver City, limestones tilted up by a mass of porphyry are cut by narrow fissures, and replaced along the fissure walls by copper and zinc sulphides. Veins in the porphyry carry copper and gold, with smaller amounts of silver, lead, and zinc.

These phenomena of contact metamorphism with sulphide formation, but without much gold and silver, are repeated from one end of the Territory to the other along the boundaries of intrusive stocks and laccoliths. The contact deposits are almost without exception accompanied by the formation of systems of fissure veins, rich in gold and silver, which chiefly cut the intrusive rock, but also penetrate across the contact. The veins have certain broadly marked characteristics. They are regular, with absence of general brecciation; in the filling quartz predominates and is apt to be coarsely crystalline, sometimes showing comb structure; a banded structure by deposition is rather common. In some cases there may be doubt as to the age of these veins, but enough is known about them to say that as a group they antedate the late Tertiary volcanic flows.

Some of the copper and lead and all of the zinc produced from the ores of the Territory have been derived from contact-metamorphic deposits. A very large part of the gold taken from the Territory has directly or indirectly—by placers—been obtained from the older fissure veins just described. Much silver also comes from this source.

It is certain that the development of these deposits can not be correlated with the ordinary circulation of surface waters, and it appears to the writers that the facts very strongly support the view that the sulphides, as well as the gold and silver, were contained in the intrusive magma; the baser metals were most readily given off at the contacts during the intrusion; the gold and silver deposition was in the main a later process; these metals were concentrated in fissures which were opened in the intrusive rocks shortly after their consolidation, and the veins, like the whole intrusive mass, have been subjected to erosion. At the time of vein formation the presently accessible parts were deeply buried.

A number of irregular lead deposits occur as replacements in the Ordovician or Devonian limestones in Sierra County, the most prominent localities being Cooks Peak, Hermosa, and Kingston; also in Grant County, where the principal producer is at Granite Gap, in the Peloncillo Range In most cases these ore bodies are close to masses of intrusive porphyries, although they are not contact deposits. In some cases they have assuredly been caused by the same waters which filled the fissure veins shortly after the congealing of the intrusive magma.

Several of the large silver deposits of Grant County form irregular replacements of pre-Carboniferous limestone and in most cases are closely associated with dikes or larger bodies of porphyry. At Silver City the ores are found in Silurian limestone immediately below the Devonian shale. At Georgetown and Lone Mountain the limestone just below these shales is likewise the ore horizon. At Lake Valley Doctor Gordon found that a thin bed at the base of the lower Carboniferous (Mississippian) limestones carries the ore. In all these cases the principal ore is the chloride of silver, although partially decomposed galena, rich in sliver, is present in most places.

The important lead, zinc, and copper deposits of the Magdalena Range near Socorro have been studied in considerable detail by Dr. C. H. Gordon, and were also visited by the authors of this paper. The sulphides form replacements in the westward-dipping limestone beds on the western side of the range; associated minerals are magnetite and pyroxene. The deposits are of contact-metamorphic origin and have probably been induced by the intrusion of a granite-porphyry or monzonitic porphyry which outcrops above and below the mines. The deposits are found at the boundary of porphyry and limestone and along particularly susceptible horizons, as below the Silver Pipe limestones. Replacement by sulphides extends up for several hundred feet from the contact.

In some instances veins cutting porphyry are not accompanied by contact metamorphic deposits. In the Jicarilla district, in Lincoln County, narrow seams with gold-bearing pyrite have furnished considerable placer gold. No sediments are known here. At White Oaks well-defined veins and irregular sheeted zones carry rich auriferous pyrite with some quartz. Some of these veins extend into the Cretaceous sediments. At Steeple Rock, in western Grant County, veins in porphyry, carrying gold and some silver, are covered by later flows of rhyolite. No sedimentary rocks were seen here.

LATER SERIES.

The fissure veins in volcanic-flow rocks are the most recent of the epigenetic deposits of New Mexico. These surface lavas are ordinarily easily recognizable as such by their structure, their bedding, and the topography of the terranes. They consist of an older series of basalts, rhyolites, and dacites, less commonly andesites, which cover the eroded surface of the intrusive rocks and the eruption of which took place in middle or late Tertiary time. Still later—in part Quaternary—is a series of basalt flows which is not known to harbor any mineral deposits. The surface lavas cover but a small part of New Mexico. The earlier flows formed the largest volcanic area of the Territory, and connect with the vast lava fields of eastern Arizona. They extend through northern Grant, southern Socorro, and northern Sierra counties, though not without interruption. Smaller areas of them are found elsewhere.

To begin from the north, the first representatives of the fissure veins in surface lavas are found at Red River in Taos County, where they cut rhyolite flows and contain gold with some silver in quartz, calcite, and fluorite gangue. Pyrite and other sulphides are also present. Farther south, at Bland or Cochiti, in Sandoval County, are gold-bearing veins concerning the age of which there is some doubt, but which probably belong to this class. The gold, accompanied by silver sulphides, is present in minute subdivisions in fine-grained almost chalcedonic quartz. Further representatives are the Rosedale veins of gold-bearing quartz occurring in the rhyolite flows of southern Socorro County, and the Chloride, Phillipsburg, Grafton, and Hillsboro veins in Sierra County, which, according to Dr. C. H. Gordon, cut andesite flows and tuffs. Most important of all are the deposits of the Mogollon Range, in the southwest corner of Socorro County, which are believed to have produced several million dollars in gold, silver, and copper. They are brecciated fissure deposits of large size, carrying finely divided gold and silver bearing sulphides in a gangue of quartz and calcite, which has partially replaced the breccia fragments. At the Cooney mine copper minerals, mainly bornite and chalcocite, are associated with quartz, calcite, and fluorite gangue.

There are indications that the vein-forming action during this last epoch has persisted up to a very recent time. At Socorro a system of silver-bearing seams of barite cuts across rhyolite at the base of the escarpment of Socorro Mountain, along which hot springs of considerable volume now issue. The Torrance mine on this belt is said to have produced $200,000. At Ojo Caliente, Rio Arriba County, a small silver and gold bearing vein with fluorite and barite gangue appears to be directly connected with a hot-spring deposit of tufa laid down comparatively recently on the present surface.

Late Tertiary veins are confined to the lava flows of the same age, and there is strong evidence that they were deposited by hot ascending waters shortly after the consolidation of these lavas. The deposits have certain broad, common characteristics; gold and silver are contained in finely divided form, and the former metal has rarely been concentrated into important placer deposits.

Fine-grained, in places chalcedonic quartz is characteristic of many of them, as is often a barite and fluorite gangue. Brecciation of the walls is common, while regular comb or banded structure is rarely encountered. Altogether the veins bear evidence of having been formed close to the surface and of having suffered little erosion since the time of their deposition. A notable quantity of the gold and much of the silver produced by the Territory has been furnished by these veins, though their importance has not equaled that of the older Tertiary series connected with the deep-seated intrusives.

The relations of the New Mexican post-Cretaceous metalliferous deposits to igneous rocks may be concisely formulated as follows:

1. Intrusions of acidic porphyries and granites as stocks and laccoliths normally produced metamorphism and accumulation of sulphides of copper, lead, and zinc, with some gold and silver, in favorable calcareous strata along the contact planes.

2. Shortly after the congealing of the intrusive magmas fissure systems were developed in the stocks and laccoliths, and in these fissures rich gold- and silver-bearing veins were normally deposited.

The contact metamorphic deposits and the veins related to them have been exposed by deep erosion.

3. The eruption and solidification of surface lavas was also followed by fissuring and the deposition of gold and silver bearing veins, but these phenomena were less normal and general than the fissuring of the intrusive stocks. They probably took place only where direct connection with the eruptive focus and with the deep-seated magmas could be established.

The veins contained in the volcanic flows have suffered comparatively little from erosion and their present level is thus near the surface of original deposition.

COPPER DEPOSITS IN SEDIMENTARY ROCKS.

Copper is widely distributed through certain sedimentary beds in New Mexico, which are usually referred to as the "Red Beds" and assigned an age varying from Upper Carboniferous or Permian to Triassic or Jurassic. Nor is this development entirely confined to New Mexico, but recurs in the Plateau Province of Utah and Arizona and extends eastward into northern Texas. In their general aspect the distribution and origin of the copper in the "Red Beds" have been discussed by Emmons.[a]

In New Mexico these cupriferous beds are exposed and have been prospected over a broad belt extending across the Territory in a northwesterly direction. The best-known occurrences are at Nacimiento and Cuba, Sandoval County; at Herosa, Rio Arriba County; at Tecolote, near Las Vegas, San Miguel County; and in the Sandia, Manzano, San Andreas, and Oscura ranges in central New Mexico. The localities where most work has been done are at Nacimiento and along the eastern base of the Oscura Mountains. In all cases the copper ores occur partly oxidized, partly as chalcocite in the sandstones. Reduction plants have been erected at Estey, in the Oscuras, as well as at Señorito and Tecolote. Shipments of glance ore have been made from the first two places, but at present these deposits, though certainly extensive, furnish only an insignificant part of the copper production of the Territory.

Opinions are very much divided as to their age and origin. Probably the most prevalent view is that the ores were deposited at the same time as the inclosing sediments by sea or lake water which contained copper in solution. The deposits are not strictly confined to the Permian or Triassic, but occur also in the lowest Cretaceous as well as the in Upper Carboniferous. Our studies of the copper-bearing sandstones have not progressed far enough to justify the expression of a definite opinion concerning them. However, the theory of deposition stated above seems improbable. At least two other possibilities exist: Either the copper was deposited by adsorption in the clayey sandstone of cupriferous solutions ascending on fault fissures, or it was leached from older deposits in adjacent ranges which may have been land areas during the deposition of the "Red Beds," carried down by the streams, and precipitated by processes of adsorption in the sediments near the shores. Leaching and redeposition may even be going on at the present time. Mr. Schrader, who has examined the deposits in the northern part of the Territory, inclines toward this second view. It is also supported by the fact that older pre-Cambrian copper deposits occur in many of the ranges, at the foot of which the cupriferous "Red Beds" extend.

There is evidence in favor of each of these hypotheses. At any rate it seems certain that precipitation by absorption from dilute solutions of copper salts[b] has played an important part in the formation of these bedded copper ores.

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[a] Emmons, S. F., Contributions to economic geology, 1904: Bull. U. S. Geol. Survey No. 260, 1905, pp. 221-232.

[b] Sullivan, Dr. E., The chemistry of ore deposition; precipitation of copper by natural silicates: Economic Geology, vol. 1, No. 1, pp. 67-73.

THE ANNIE LAURIE MINE, PIUTE COUNTY, UTAH.

By Waldemar Lindgren.

Location.—The principal part of the gold and silver mined in Utah is derived from a few camps to the east and south of Salt Lake, such as Park City, Bingham, Mercur, and Tintic. A broad strip comprising nearly half of the State and including almost all of the eastern counties belongs to the Plateau Province and contains few if any deposits of precious metals. This is true also of the southern-central counties, which likewise form a part of the Plateau Province. The western tier of counties, adjoining Nevada, contains among its many desert ranges scattered deposits of gold and silver, but few of them have attained any noteworthy production.

About the year 1900 statements began to appear in the press concerning a new gold discovery of importance in the southern-central portion of the State, in Piute County. This deposit, which is known as the Annie Laurie mine, has amply verified the predictions regarding its value, inasmuch as its production during the last few years amounts to over $2,000,000.

The Annie Laurie mine is situated 175 miles south of Salt Lake City, on the west side of Sevier Valley, in Piute County, just over the line from Sevier County. The region was known to be mineral bearing from the earlier days, for the deposits of Marysvale and Bullion Creek are located in the same vicinity, a few miles to the southeast; but in the new district, which is named the Gold Mountain, no productive mines had previously been developed. The district was discovered about fifteen years ago, but as the ores did not prove amenable to the ordinary amalgamation process, the primitive reduction works erected were a complete failure. With the advent of the cyanide process a method was found which permitted the successful working of the ores, and the present mill was built at the mine by the Annie Laurie Mining Company in the year 1899. The production of gold and silver of the mine since that time has amounted to $2,100,000, or about $400,000 a year.

Development.—The deposit, which is to be classed with the fissure veins, is located at an elevation of about 9,600 feet on the northerly slopes of that cluster of high peaks which culminate with elevations of over 12,000 feet in the Belknap and Delano mountains. The development, which extends over a horizontal distance of 2,400 feet, is effected by four principal tunnels, the upper one called the Blue Bird and the lower three referred to as No. 3, No. 4, and No. 5. The vertical distance between the Blue Bird and No. 5 tunnel is 800 feet. All of the tunnels are crosscuts, and the lowest one penetrates the barren rock for over 3,000 feet until it strikes the vein. In all, the tunnels and crosscuts aggregate several miles in length.

The reduction of the ore is carried on by means of a dry-crushing process, followed by cyanide percolation and amalgamation. The mill, which has a capacity of 200 tons and which is expected to be enlarged to 300 tons, crushes the quartz by four sets of rolls to a 40-mesh screen. The percolation takes place in the usual large tanks and occupies a period of eight days. The amount of sulphides in the ore is exceedingly small, so that concentration on tables is deemed unnecessary. From the cyanide vats the pulp goes to the amalgamating tables, where the coarser gold which may have remained unattacked by the cyanide is finally caught. In the mill now under construction at an adjacent mine by the Sevier Consolidated Gold Mining Company a somewhat different plan is adopted, including concentrating on tables, as well as plate amalgamation and cyaniding.

Geology.—About 100 miles south of Salt Lake City the railroad enters the characteristic Plateau Province, where the strata lie horizontal and little evidence of volcanic action is seen. For 70 miles the road ascends the broad Sevier Valley to its terminus at Marysvale. Cliffs of light-colored reddish or white beds belonging to the Tertiary form a conspicuous wall on the west side, while to the east rises the broad Wasatch plateau, capped by rocks of the same age. Near the town of Richland darker volcanic masses begin to appear on both sides of the valley; their character as flows covering the Tertiary rocks is clearly indicated. This region has been described in considerable detail by Major Dutton in his report on the High Plateaus of Utah.[a] He shows on the west side of the upper Sevier Valley a large area of rhyolite culminating in the peaks of Belknap and Delano, which practically overlook Marysvale. On the east side of the valley the heavy volcanic masses consist, according to Major Dutton, of a trachytic rock.

At the little station of Sevier (elevation, 5,557 feet), a few miles north of Marysvale, the valley contracts, and for a short distance the river flows through a deeply cut canyon in the rhyolitic rocks, evidently excavated since the eruption of the rhyolites, which appear to have formed a temporary dam across the valley. The area indicated on Dutton's map as rhyolite covers at least 1,500 square miles. Over the larger part—that to the north of the higher peaks—the rocks are tuffaceous and more or less clearly water-laid. The wagon road from Sevier to the Annie Laurie mine follows up Clear Creek in a westerly direction between cliffs of well-bedded, light rhyolite tuffs. Eight miles from Sevier it turns southward into the canyon of Mill Creek and from that point rapidly ascends toward the higher central peaks in the range, at the northern foot of which the mine is located. Well up toward the summits the tuff is replaced by massive, light-colored rhyolite, easily breaking into small fragments, which form long white talus slopes along the sides of the ridges. Broad views open toward the north, where the rhyolite tuffs extend for more than 25 miles as a monotonous, high, arid plateau, dotted here and there with a scant vegetation of junipers. From points a short distance north of the mine long and broad but gentle slopes begin, partly covered with bunches of fir and dotted in the autumn with brilliant foliage of aspens and low bushes. These long slopes extend up from the plateau level toward the highest peaks, of which only one, called Bare Mountain, is visible from this point. A number of them exceed 12,000 feet in elevation and are among the highest in Utah. The rhyolite continues almost up to the mine, which is situated at the point where Mill Creek begins to expand into a glacial amphitheater and where the little mining town of Kimberly has obtained a precarious foothold on one of the steep rhyolite slopes. The upper basin of Mill Creek is occupied by a massive greenish-gray rock, much chloritized, and showing small crystals of feldspar. This is the country rock in which the deposits occur. Microscopical examination shows it to contain a considerable amount of quartz in the groundmass, while the phenocrysts are in part alkali feldspar and in part moderately basic soda-lime feldspar. There are also small foils of biotite, usually more or less completely converted into chlorite. On the whole, the rock should probably be classified as a dacite. This area probably extends southeastward across the summit of the range toward Marysvale. Near the Sevier mine and on the ridge between the Sevier and Annie Laurie dikes of dioritic or monzonitic rocks appear. These are dark green and contain no quartz. One of these dikes outcrops close to the Sevier mine, but it is not evident that any close connection exists between the dike and the deposit. The veins are wholly in the dacite.

From the summit a sharp descent leads down toward Marysvale, and in the lower part of Bullion Creek, according to Dutton, outcrops of a quartzite occur, which are referred by him to the Jurassic.

Ore deposits.—The deposits occur in well-defined quartz veins cutting through the core of this old volcanic district. As far as known, no deposits occur in the rhyolite or in the great masses of rhyolite tuffs to the north of the Annie Laurie. They are confined to the dacite already mentioned as occurring near the mines. The Annie Laurie vein courses nearly north and south and dips from 45° to 60° W. About a mile to the west is a parallel vein called the Sevier, on which the Sevier Mining Company is now erecting a mill. The extension of the Sevier toward the north is being sought for in the Holland tunnel.

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[a] U. S. Geog. and Geol. Surv. Rocky Mt. Region, 1880.

The Annie Laurie vein is very poorly exposed on the surface, being largely covered by morainal material. There is, however, a large outcrop rising boldly above the Blue Bird tunnel, and this formed the point of discovery. The vein has not been found on the surface at any point north of this. Within a moderate distance north from the northernmost workings the Annie Laurie vein should enter the rhyolite. How this will affect the deposit is as yet problematical. On the surface none of the productive veins appear to occur in this rock.

The quartz forms an almost continuous sheet along the vein, rarely less than 3 feet in thickness and often expanding to a width of 20 feet or more. As a rule the walls are poorly defined and slickensides indicating motion are rare. In places it contains, parallel to the walls, streaks of iron oxides and black, sooty, manganese ores. Near the walls the vein very commonly shows brecciation, and the quartz here often contains abundant and sharply-defined inclusions of country rock. While it is almost impossible to obtain fresh rock at any place in the mine, and chloritization as well as carbonatization have frequently occurred, the rock is not changed very much in appearance, and the included greenish fragments are sharply outlined against the white quartz.

The mine workings have not penetrated below the zone of oxidation, and neither the quartz nor the country rock seem to contain any unoxidized sulphides. In only one place, in the crosscut of the lowest tunnel, was some fresher dacite found which contained specks of pyrite.

In addition to the regular vein, which is often referred to as the East vein, there is also in certain parts of the workings a smaller fissure which lies a short distance to the west and which differs in some respects from the former. Its quartz contains more gold, its vein is narrower, and slickensides appear sometimes on the walls. It is principally known from No. 3 tunnel, in the richest part of the vein.

Two faults with a throw of 20 and 40 feet are known on the Blue Bird and No. 4 levels, but on the whole the vein is little disturbed.

The ore consists of a white, normal vein quartz, often very friable, breaking easily into small fragments. It is sometimes drusy, but more commonly massive. Calcite is abundant in certain parts of the deposit, but has often been dissolved by surface waters, leaving a hackly or lamellar quartz of striking appearance. As a rule no ore minerals are visible, although on panning the quartz may yield a little visible gold. The pyrite which the ore contained is doubtless converted to limonite, while the decomposition of the carbonates has resulted in the formation of oxides of manganese as well as more limonite. A slight copper stain appears in places, especially where the ore is rich. Finely divided argentite is no doubt present, but only in small quantities. On concentration the ore yields a very small quantity of sulphides, which are extremely rich in silver.

The value of the gold in the ore exceeds that of the silver. Samples of ore of the East vein yield, for instance, gold, $12; silver, $2.30; or gold, $5.60; silver, $2.05. Samples from the West vein contain, for instance, gold, $11; silver, 32 cents; or gold, $4.80; silver, 68 cents. The richest ore is stated to assay from $15 to $18 per ton, odd samples frequently rising to $100 per ton. The average value of the ore is said to be between $7 and $8 per ton. The bullion obtained from the zinc boxes is stated to be 0.925 fine. One analysis shows 230 parts of gold, 695 parts of silver, 65 parts of zinc, and 10 parts of copper, the zinc being derived from the shavings in the boxes. The average bullion would contain about 750 parts silver and 250 parts gold.

The ore of the Sevier mine is in general similar to that of the Annie Laurie, although a drusy structure is more common; in places well-crystallized masses of amethyst-colored quartz appear. It is said that 22 per cent of the gold values and 7 per cent of the silver are recovered on the plates in the amalgamation, which here is the preliminary process. A considerable amount of argentite is present in finely divided form, and panning also yields a little fine gold.

The ore shoots of the Annie Laurie vein have an ill-defined lenticular form when projected on the plane of the vein, and appear to pitch 45° or less to the north. Some of them at least have cores consisting of bunches of rich ore, gradually decreasing in tenor toward the outside. On No. 3 level in the shoot the vein is in places 23 feet wide.

Conclusions.—The ore deposits of the Gold Mountain district possess, in some of their aspects, more than local interest. We find here in the plateau country of southern Utah an isolated volcanic eruption of rhyolite of middle Tertiary age, the central points of which now form some of the highest peaks of the State. Over wide areas around these peaks extend broad plateaus of tuffs—all of them barren of mineral deposits. The ore deposits are found in the focus of igneous activity. On the north side of the peaks lies the Gold Mountain district of quartzose gold-silver ores. On the southeast side, near Marysvale, where the core has been deeply trenched by Sevier River, are the old mining districts of Ohio and Mount Baldy, in which there is but little activity at the present time.[a]

The Annie Laurie, as to country rock, ore, and structure, is an almost exact counterpart of the Waihi deposits in New Zealand, though it does not possess the great number of veins nor the enormous amount of ore exhibited by the latter bonanza. In many respects it is also similar to the De Lamar deposits of Idaho.

These veins are believed to have been deposited by hot springs in fissures as a last phase of volcanic activity shortly after the close of eruptions and not far below the actual surface of that epoch.

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[a] Most of the Marysvale deposits are said to contain lead, zinc, and copper. Selenide of mercury (tiemannite) occurs in the Lucky Boy and other mines in the Baldy district and during 1886 and 1887 was even mined on a commercial scale. In this connection it should be stated that mercury in some form is also reported to occur in the Gold Mountain mines.

SURVEY PUBLICATIONS ON GOLD AND SILVER.

The following list includes the more important publications by the United States Geological Survey on precious metals and mining districts. Certain mining camps, while principally copper producers, also produce smaller amounts of gold and silver. Publications on such districts will be found in the bibliographies for copper on pages 144 and 145 and for lead and zinc on page 166. For a list of the geologic folios in which gold and silver deposits are mapped and described, reference should be made to the table on pages 8 and 13 of the present bulletin:

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——— Gold fields of the southern Appalachians. In Sixteenth Ann. Rept., pt. 3, 251–331. 1895.

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Irving, J. D. Ore deposits of the northern Black Hills. In Bulletin No. 225, pp. 123–140. 1904.

——— Ore deposits of the Ouray district, Colorado. In Bulletin No. 260, pp. 50–77. 1905.

——— Ore deposits in the vicinity of Lake City, Colorado. In Bulletin No. 260, pp. 78–84. 1905.

Lindgren, Waldemar. The gold-silver mines of Ophir, California. In Fourteenth Ann. Rept., pt. 2, pp. 243–284. 1894.

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PURINGTON, C. W. Preliminary report on the mining industries of the Telluride quadrangle, Colorado. In Eighteenth Ann. Rept., pt. 3, pp. 745–850. 1898.

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COPPER.

THE COPPER MINES OF THE UNITED STATES IN 1905.

By **Walter Harvey Weed.**

INTRODUCTION.

Copper mining in the United States has had a marvelously rapid development in the last ten years, showing an increase of 150 per cent in that time. The production for 1905 broke all previous records and brought higher prices than at any time for ten years past. The greatest increase in production was in Arizona, and the greatest individual increase that of the Copper Queen mine at Bisbee, Ariz. The following table shows the production and relative rank of the different producing States, the figures for 1904 being those prepared and published by the Geological Survey,[a] while those for 1905 are compiled from estimates by various trustworthy authorities.[b]

Production of copper in the United States, 1904–5.

State or Territory.	1904.	1905.	State or Territory.	1904.	1905.
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*
Montana	298,314,804	319,179,885	Wyoming	3,565,629	2,393,201
Arizona	191,602,958	222,866,024	Alaska	2,043,586	4,703,600
Michigan	208,309,130	218,999,753	Idaho	4,518,034	6,661,400
Utah	47,062,889	51,950,789	Oregon and Washington.		1,550,000
California	28,529,023	[a] 20,000,000			
Tennessee	15,211,086	14,507,982	North Carolina		700,000
Colorado	9,506,944	9,854,176	Georgia		10,000
New Mexico	5,368,666	5,638,842	Total	814,035,719	879,015,652

[a] Salt Lake Mining Review, Annual Review number, January, 1906.

The proportion furnished by the United States and the leading part it plays in the copper market of the world are shown in the following table, giving the production for 1904:

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[a] Mineral Resources U. S. for 1904.

[b] Eng. and Min. Jour., April 28, 1906; Stevens, Horace J., Mining World, Jan. 27, 1905; and information furnished the writer by mine owners and managers.

Production of raw copper, 1904, including both native and foreign ores, smelted and intermediate products, raw copper to be refined, and supplies of refined, in metric tons.[a]

Germany		30,262
Great Britain		65,500
France		7,000
Austria-Hungary		1,463
Italy		3,700
Russia		10,900
Imported into Europe from United States		245,000
Imported into Europe from Chile		22,000
Imported into Europe from Japan		3,850
Imported into Europe from Australia		12,200
Imported into Europe from other countries (Mexico, East India, and Canada)		10,000
Imported into Asia from Japan and Australia		38,000
Imported into Asia from America and Europe		7,300
United States product		378,000
Less export to Europe	255,934	
Less export to America and Asia	6,800	
		262,734
United States supply, 1904		115,266

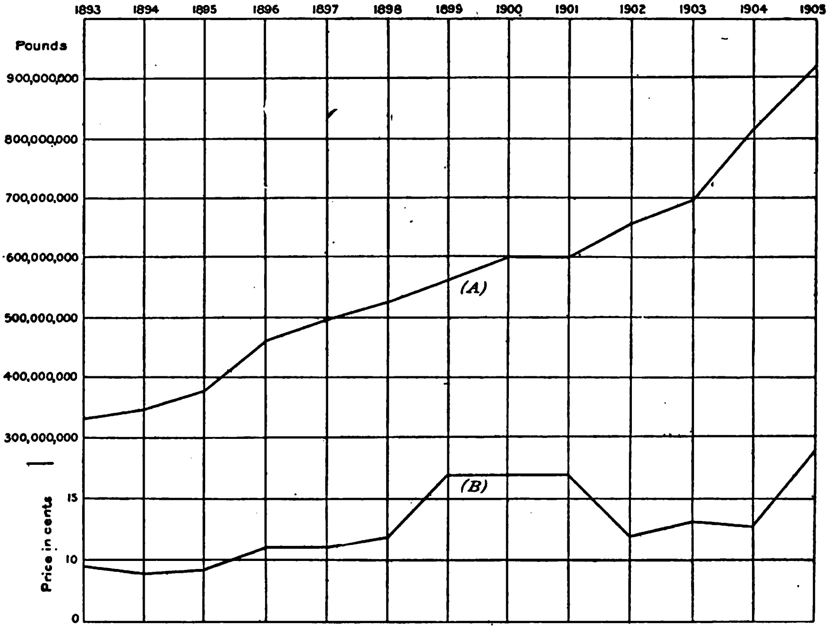

FIG. 5.—Diagram showing (*A*) production and (*B*) prices of copper in the United States from 1893 to 1905.

The copper mines of the United States yield gold and silver as by-products and many gold mines yield small amounts of copper. The total gold produced by the copper mines of the United States in 1904 was 237,116 ounces, distributed as shown in the table below:

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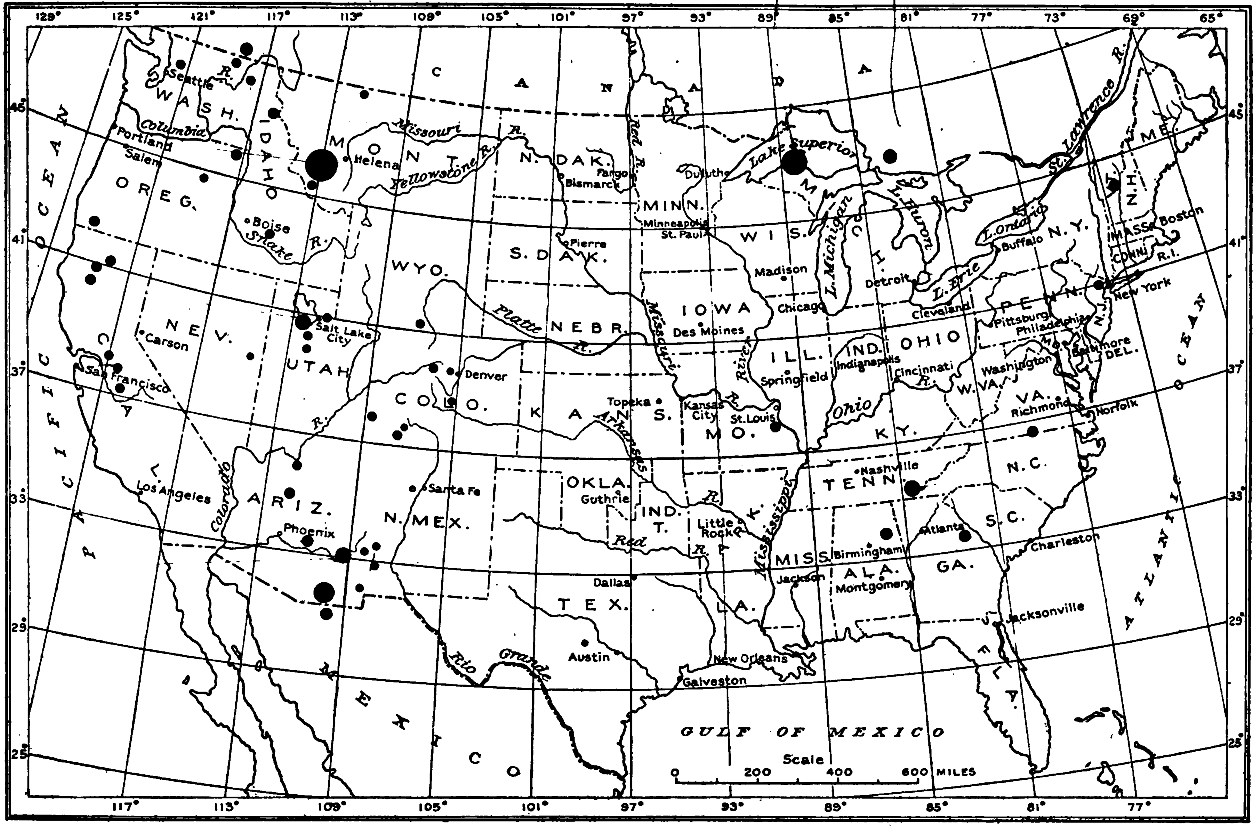
[a] Metal. Gesell., 12th annual issue, October, 1905.



MAP SHOWING THE DISTRIBUTION OF THE PRODUCTIVE COPPER MINES OF THE UNITED STATES.

Size of dot represents approximately the relative importance and production.

Precious metals contained in the copper ores of each State.

	Gold.	Silver.		Gold.	Silver.
	Ounces.	*Ounces.*		*Ounces.*	*Ounces.*
Utah	109,968	2,572,582	Idaho	538	201,843
Arizona	47,563	1,464,731	Wyoming	326	4,601
Montana (Butte)	44,400	10,236,119	Oregon	326	11,677
California (Shasta)	24,727	844,265	South Dakota	145	789
New Mexico	4,137	79,369	Nevada	10	2,519
Colorado	3,288	131,695	Michigan		122,807
Appalachian States (estimated)	1,066	79,600	Total	237,116	15,768,307
Washington	582	16,710			

The distribution of the copper mines of the country is shown in Pl. III.

The Butte, Mont., copper district is the greatest silver-producing camp of the entire world, its production being 10,236,119 ounces in 1904. Utah leads in the amount of gold produced from its copper ores, Bingham and Tintic yielding 109,968 ounces, the ores also carrying 2,572,582 ounces of silver. The Arizona mines yield more gold than the Butte mines, but far less silver.

GENERAL CONDITIONS.

The marked change from lead to copper as a collector of precious metals in smelting practice is one of the notable features of recent years and has furnished a market for gold and silver ores whose copper content was not formerly paid for, 3 per cent copper being long considered the minimum.

The most striking feature of copper mining in the last two years is the complete success of experiments made in the treatment of the so-called disseminated ores, in which small particles of copper sulphides occur disseminated through altered porphyry. Enormous bodies of this class of ore occur at Morenci, Ariz., at Bingham, Utah, and at Ely, Nev., that were formerly considered of too low grade to work, but that have been proved to yield a handsome profit when treated in concentrating mills and concentrated 10 to 20 into 1.

The extent to which these great bodies of "disseminated" ore will contribute to the world's supply of copper can be estimated from the fact that preparations are being made to mine and mill 12,000 tons of this ore a day at Bingham and nearly as much at Ely, while the mills of both the companies at Morenci have been greatly enlarged. Although similar disseminations of glance and pyrite in altered granite alongside of and between the veins at Butte, Mont., have long been milled, it has been customary to regard a 3 per cent or even a 4 per cent ore as the lowest grade that could be profitably treated, whereas at the localities mentioned above the grade is much lower, as shown by the following table, after J. P. Channing:

Tenor of "disseminated" copper ores.

	Per cent.
Morenci, Ariz., Arizona Copper Company	2.6
Morenci, Ariz., Detroit Copper Company	3.0
Bingham, Utah, Utah Copper Company	1.9
Bingham, Utah, Boston Consolidated Copper Company	1.4
Ely, Nev., Nevada Consolidated Copper Company, Ruth mine	2.6
Ely, Nev., Nevada Consolidated Copper Company, Eureka mine	2.2

It is evident that the price of the metal will determine the minimum grade of copper ore that can be treated at a profit. The above ores can be made to pay with copper at 12 cents a pound.

The widespread adoption of so-called pyritic or raw-sulphide smelting, in which the fuel value of the sulphur is utilized, has had its effect on copper mining, as, indeed, have the introduction of labor-saving devices at the smelters and the improved mechanical arrangements which have lowered the cost of treatment and so led to the mining of lower-grade ores. The cheapened smelting costs have added a long lease of life to various old properties by enabling bodies of lean and previously unworkable ores to be reckoned as ore reserves, while pyritic smelting has led to a demand for pyritic ores as a fuel flux to be added to siliceous ores.

If it be true, as an eminent metallurgist has epigrammatically expressed it, that "roasting is a crime and concentration a felony," the ores now concentrated will some day be treated direct in the blast furnace, mixed with pyritic ores, as is now being done at the Pittsmont smelter at Butte.

It has not been found practicable nor is it especially desirable to separate the production of milling and of smelting ores. At Butte, Mont., the smelting ores form from 6 to 10 per cent of the total amount mined, the proportion varying at the different mines. The entire production of the Utah and of the Boston companies of Bingham, Utah, will be milling ores, and at everyone of the Arizona camps the proportion of milling ores used is increasing each year.

The California ores, like those of Ducktown, Tenn., are basic sulphide ores, an ideal material for pyritic smelting.

Copper ores can be grouped commercially into smelting, concentrating, and leaching ores. All three kinds of ore often occur at the same mine, but the distinction holds good in a general way. Smelting ores may be either pyritic, with an excess of iron, or siliceous, carrying an excess of silica, though the lower-grade siliceous ores are often classed as concentrating ores. Pyritic ores are found at Ducktown, Tenn., and at the mines of Shasta County, Cal., while the smelting ores of Butte are well-known examples of siliceous ores which need basic flux added to them to insure successful treatment.

In some cases, owing to the physical character of the ore and the minute intergrowth of ore and gangue minerals, concentration is not feasible. In such cases direct smelting with the production of a low-grade matte is possible, provided basic ores can be obtained. In any case the loss in wet concentration is considerable, varying from 20 to 35 per cent.

In recent years self-fluxing ores have been found at a few localities—as, for example, at the Boundary Creek region in Canada and in the mines of the Saddle Mountain Company on Gila River, Arizona—and in such cases ores particularly low in copper may be treated at a profit, provided coke can be obtained at a reasonable figure. The utilization of low-grade garnetiferous contact-metamorphic ores is still a problem for the metallurgist, and although various attempts have been made to treat such ores, particularly in the San Pedro mines in New Mexico, success has not been attained.

The Lake Superior ores may be called ideal concentrating ores, as the native metal is tough and does not slime, as do the brittle sulphides when they are pulverized to liberate the metallic contents.

From a geological standpoint the producing copper deposits of the United States may be grouped as follows:

(*a*) Deposits in altered limestones, showing contact-metamorphic characters, and adjacent to eruptive rocks (Morenci type) in part characterized by deposits of group *b*.

(*b*) Deposits in fissured and altered igneous rocks, in part as veins, in part as dissemination and impregnation of shattered or porous rocks of other kinds (Morenci).

(*c*) Replacement veins in sheeted granitic rock (Butte type).

(*d*) Lenticular masses of solid, nearly pure, pyritic ore in shear zones in igneous rocks (Shasta County type).

(*e*) Lenticular deposits (similar to *d* in shape and mineral character) in metamorphic schists (Ducktown, Tenn.; Ely, Vt.).

(*f*) Deposits of native copper in altered amygdaloidal basic lava and interbedded conglomerates (Lake Superior).

(*g*) Normal fissure veins and impregnations of similar genesis.

Other types of scientific but slight economic importance also occur—as, for example, the deposits in the glance-impregnated quartzites of the Permian Red Beds, the impregnated shales adjacent to trap sheets in New Jersey, the Blue Ridge deposits of Virginia, etc.—but they need not be considered here.

The class first named, the contact-metamorphic deposits, yield about one-fifth of the total copper produced in this country. The allied disseminated ores yield about 50,000,000 pounds, excluding Butte's production. The Michigan production of 221,000,000 pounds for 1905 is all from one type of deposit, while the lenticular deposits (*d* and *e*) yield 36,000,000 pounds. The grouping given above is intended to express broad features and is not given as a satisfactory classification. Form is an important factor from the mining standpoint; mineral character of ore and of gangue from the smelter's point of view.

The first group, which for convenience may be called the Morenci type, should really include groups *a* and *b*. At each of the great mining centers—Morenci and Bisbee, Ariz.; Cananea, Mexico; Bingham, Utah, and Ely, Nev.—the distribution of the copper deposits is coextensive with a great porphyry stock and its dike systems. Areas devoid of intrusions are barren. The deposits are essentially copper deposits, with very minor amounts of gold and silver. The workable deposits of these localities occur either in the limestones or in the porphyry. In limestone they are confined to areas showing marked contact metamorphism, and the sulphides replace the original rock material, are intergrown with the contact minerals, and were introduced during the metamorphism of the limestone. The prevalent minerals are cupriferous pyrite and chalcopyrite.

The disseminated ores and associated fissure-vein deposits carry pyrite, with or without chalcopyrite and often with zinc blende and molybdenite, with but little quartz gangue, in altered porphyry. The ores are of low grade and in many cases workable only as far down as secondary reconcentration (enrichment) has occurred. The porphyry is altered, usually greatly so, by late hydrothermal action, in the latter case consisting of sericite, quartz, and pyrite. Where the fissures pass into other rocks alteration and ore deposition also occur, except in those already altered by contact action.

RECENT LITERATURE.

During the last few years several important papers describing copper deposits have been published. Among the Survey publications the monographs on Globe, Bingham, Bisbee, Encampment (Wyoming), and Morenci have appeared as Professional Papers.[a] Shorter papers in Bulletins Nos. 213, 225, and 260, Contributions to Economic Geology, 1902, 1903, and 1904, have contained descriptions of Butte, Mont., and the deposits of Shasta County, Cal. The rocks, but not the ore deposits, of Lake Superior have been described by Irving in Monograph V. The copper deposits of eastern Oregon are described in The Gold Belt of the Blue Mountains of Oregon, by Lindgren.[b] The copper deposits of the Cœur d'Alene district, near Mullan, are described by Ransome in a preliminary report in Bulletin No. 260, and a more detailed paper is soon to appear. The deposits of the eastern United States are described in a forthcoming bulletin.

ALASKA.

The first commercial shipments of copper from Alaska were made in 1903, forming, it is hoped, the beginning of a great industry. At the present time the known copper mines of Alaska do not warrant definite estimates of future production.

On Prince of Wales Island two properties have been brought to a producing stage and are now reducing their own ores. The first is the Mamie mine at Hadley, operated by the New York Smelting and Refining Company. The ore is chalcopyrite, with pyrite, a very small amount of calcite, and much amphibole. The ore occurs in lenticular masses surrounded by black slickensided surfaces. It is understood that an arrangement has been made by which the company exchanges ore with the Britannia Company, near Vancouver, sending it the basic ore and receiving in exchange the highly siliceous ores of the Britannia mine. The Coppermount smelter was also in operation in the latter part of 1905 and promises to be a steady producer in the future.

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[a] Nos. 12, 38, 21, 25, and 43, respectively.
[b] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1901, pp. 551-776.

One mine on Prince William Sound was a steady producer during 1904, shipping ore to the Puget Sound smelter.

The Nikolai greenstone forms a remarkable body of igneous rock, extending along the Alaska Range for nearly 300 miles, lifted and upturned with the Carboniferous limestone about its borders, but not breaking through the rock or sending out dikes or arms into it. This great body of rocks, which consists mainly of intrusive masses, but in part contains amygdaloidal surface lavas, is cupriferous over a very extensive area, and in places, as at Bonanza Creek (Copper River) carries disseminated bornite and veins of glance in what appears to be fresh rock, together with associated magnetite and pyrrhotite.[a] According to Schrader and Spencer the Nikolai greenstone consists of volcanic flows varying laterally and vertically and constituting a unit compared with adjacent rocks. It is composed of green to red feldspar, with augite, a less amount of chlorite, a little serpentine, and some accessory magnetite. The rocks are mainly altered basalts. Locally they contain metallic copper, which is secondary. Both the greenstone and the adjacent sedimentaries are fractured and the fissures become veins. The copper occurs in the fissures in the greenstone or in the sedimentaries only near the contact with the greenstone.[b]

The best-known mines of the Prince William Sound or Copper River district are in the Bonanza Creek basin, which lies across the range from the coast and is reached by a two weeks' journey with saddle and pack mules. The ore occurs in a vein which crosses at 90° the contact between the Nikolai greenstone and Carboniferous limestones upturned about it. The vein shows a pay streak of 4 feet of 40 to 50 per cent ore, consisting of bornite and glance, the vein itself being about 11 feet wide, if the parallel fissuring is included. The fracture is distinctly traceable into the limestone, where, however, it is barren and filled with limestone fragments cemented by calcite. The vein was traced by H. V. Winchell for over half a mile into the limestone and, being above timber line, it is well exposed, particularly where it crosses a 70-foot cliff. Although carefully examined and sampled it does not show even a trace of copper throughout this extent in the limestone. The ore occurs only where the vein is incased in the greenstone, and a 40-foot shaft sunk in the greenstone shows this ore to be a surface enrichment.

ARIZONA.

Mining is Arizona's chief industry, and copper the principal product, the Territory being second in the United States and fourth in the world in the amount of its copper production.

Production of copper in Arizona, 1903 and 1904, by counties.

County.	1903.	1904.	County.	1903.	1904.
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*
Cochise	63,264,488	90,850,611	Pinal	84,000	186,638
Coconino and Maricopa	257,022	333,754	Santa Cruz	4,162	27,000
Gila	7,740,843	14,677,561	Yavapai	23,999,628	30,826,286
Graham	52,839,856	59,537,295	Yuma	9,043	1,200
Mohave	31,931	1,480	Total	148,245,973	199,481,044
Pima	15,000	3,039,219			

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[a] For a description of the Nikolai greenstone see Schrader, F. C., and Spencer, A. C., Geology and mineral resources of a portion of the Copper River district, Alaska: House Doc. No. 546, 56th Cong., 2d sess., 1901.

[b] For details concerning the copper deposits of various localities see op. cit., pp. 82, 89.

Within the last decade the industry has shown an enormous increase. Copper ores occur in nearly every county of the Territory, but the production is almost entirely from four somewhat widely separated districts—Bisbee, Cochise County, 6 miles north of the Mexican border; Morenci and Metcalf (Clifton district), Graham County, on the southern border; Globe, Gila County, near the center of the Territory; and Jerome, Yavapai County, in the north-central portion.

There are about forty producing copper mines, situated in eleven out of the thirteen counties of the Territory. The largest production is from Bisbee, which has seven producing mines; the second largest from Morenci, with five producing mines, and the third largest from Jerome, with eight producing mines. The copper output is treated in eight smelting plants and there are several idle plants which were not in operation during the year.

The Territory has shown an increase both in the production of copper and in the number of properties developed during 1905. The production for 1905 was 230,000,000 pounds.[a]

The greatest activity has been in the Bisbee district, where the Copper Queen mines have maintained their supremacy, producing some 77,000,000 pounds of copper. The so-called Bonanza Circle group of mines has been successfully developed, the greatest production coming from the Calumet and Arizona, whose smelter produced approximately 34,000,000 pounds.[a]

The copper smelter at Douglas, situated on the line between Arizona and Sonora, has been increased in size and is now capable of handling about 3,000 tons a day, or 50 per cent more than heretofore. This increase in size has been for the purpose of doing custom work, and the smelter now handles ores from the Globe district, from the Imperial mine, and from various small mines situated in the Dragoon and Santa Rita mountains.

The United Verde smelter, which does very little custom work, yielded about 40,000,000 pounds of copper.

The Equator mine, which was equipped and entered the list of producers in 1905, is now (February, 1906) closed down. This mine is the property of Hon. W. A. Clark.

BISBEE DISTRICT.

The copper output of Cochise County is nearly equal to that of all the rest of the Territory, and the copper ores of the Bisbee camp contain most of the gold and silver credited to the county. The chief producers are the Copper Queen, Calumet and Arizona, and Lake Superior and Pittsburg companies. The Bisbee district, or, as it is officially known, the Warren district, is the great center of mining production, but the ores are shipped to Douglas, on the the Mexican boundary line, where they are treated, together with ores from Nacozari and from various small properties on both sides of the line. The gold and silver values of the Bisbee ores are rather low, though the total output is considerable.

The Bisbee district produced 378,047,240 pounds of copper up to the end of 1902, entirely from the Copper Queen mine. To this may be added about 2,000,000 pounds from other properties. The Copper Queen workings cover half a square mile and the ore is developed to a depth of 950 feet. The Calumet and Arizona is now 1,200 feet deep; the Lowell shaft 1,200 feet; the Cole shaft 1,200 feet; the Calumet and Pittsburg 950 feet; the Bisbee West 700 feet; the Junction shaft 1,000 feet; the Briggs shaft 1,140 feet; the Hoatson shaft 850 feet, all in limestone, and the Saginaw shaft 900 feet. The Cole shaft of the Lake Superior and Pittsburg Company is now yielding ore from the stopes above the 1,000-foot level which carries 15 to 35 per cent of copper. The Saginaw shaft encountered ore at 700 feet and sinking is still going on.

The extraordinary success in developing new ground in an old district attained by the Bonanza Circle group of mines makes a knowledge of the geology of the district and the mode of occurrence of the ore bodies of great interest. The following notes are abstracted from the report by F. L. Ransome:[b]

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[a] Douglas, James, Eng. and Min. Jour., Jan. 6, 1906.

[b] Prof. Paper U. S. Geol. Survey No. 21, 1904. See also Contributions to Economic Geology, 1902; Bull. U. S. Geol. Survey No. 213, 1903, p. 152.

The Bisbee district is in the central part of the Mule Mountains, a few miles north of the Mexican line.

The principal ore bodies lie south of and within a mile of Bisbee. They occur in Carboniferous limestone, on the southwest side of a great northeast-southwest fault, closely associated with a boss of granite-porphyry. The limestones form a synclinal basin cut across the center by the fault. The ore occurs in roughly sheet-like masses more or less parallel to the bedding of the limestone and mostly within 1,000 feet of the fault or the granite-porphyry intrusion. Under the town the ore comes to the surface and is worked down to 400 feet, but it occurs at increasing depth to the southeast, and in the Calumet and Arizona mine was first found at a depth of 800 feet, thus indicating that the depth of the ore increases toward the center of the local basin formed by the beds, though it is not confined to any one horizon.

Thus far all the ore bodies, save the extreme western ones of the Copper Queen, lie in the Carboniferous limestones. Though these flat ore bodies lie with the bedding, their occurrence is dependent on other features. Large masses of low-grade, partly oxidized pyrite ore occur along the contact between porphyry and limestone. Other large ore bodies turn down alongside porphyry dikes, and fissures in the limestone influence distribution of the ore. The disseminated pyritic ore of the main porphyry mass of Sacramento Hill has not so far proved workable.

The "cave" ores of malachite, azurite, etc., for which Bisbee was so long famous, are now exhausted. The ores now mined consist of pyrite, with variable amounts of chalcocite and chalcopyrite. There is an observed relation between permeability and good ore.

Ransome, in his report, pointed out the probable occurrence of the then unknown ore bodies south of the porphyry boss in the following words:

> It may be pointed out that less than half of the semicircular mineralized zone (Bonanza circle) about the porphyry mass of Sacramento Hill has been explored at all. * * * There still remains an extensive area of unknown but promising ground lying south of Sacramento Hill and extending eastward toward the southeastern continuation of the Dividend fault, an area here concealed by the Glance conglomerate.
>
> But, judging from surface indications, there has been considerable mineralization of the Naco limestone south of Sacramento Hill, and there is nothing improbable in the occurrence of high-grade ores in this limestone at stratigraphically higher horizons than those in which ore bodies have hitherto been found.

Recent work by the Copper Queen Company along the Czar fault, a feature not known prior to the work of Ransome for this Survey, has led to the discovery of new ore bodies.

Coconino County contains a small producing copper mine near the Grand Canyon. The geology of this mine was treated by S. F. Emmons in the Economic Bulletin for 1904.[a]

GLOBE DISTRICT.

The principal mines of the Globe district, Gila County, are the Old Dominion and United Globe properties, the Summit group, and the Buffalo Mountain. There were 11 producing properties in 1904. The mines produce about 3,400 tons a month, having an average value of about $18 a ton. The gold content is insignificant, amounting to but a few cents a ton, and the silver content but slightly more.

The mines of the Globe district have been further developed, the output for the year 1905 approximating 28,500,000 pounds, which includes some custom ore, and about 5,500,000 pounds of copper from the Copper Queen mine shipped to Globe as sulphide ore to mix with the oxidized ores. The change in smelting from the old method of treating oxidized ores direct to the modern practice of matte smelting and bessemerizing has led to an increased output and decreased costs. The concentrating mill built by the Old Dominion Company and put in operation in August, 1905, will add materially to the output, and the draining of the deeper levels will, according to Doctor Douglas, reopen rich ore bodies inaccessible for some time past.

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[a] Bull. U. S. Geol. Survey No. 260, 1905, pp. 230-231.

The production of the Globe copper camp comes mainly from one mine—the Old Dominion. According to Ransome,[a] who made a detailed study of the region, the chief production of the district is from ore bodies in limestone and shattered quartzite, with lesser amounts from stringer lodes in diabase (pyrite ores of the Old Dominion and the Grey mines) and replacements of dacite tuff (Black Copper mine).

The important ore bodies of the district are all in limestone and quartzite, and lie on the southeast side of the great displacement which separates the sediments from diabase and is known as the Old Dominion fault. The limestone is 350 to 550 feet thick and rests on the quartzite. The ore bodies in limestone are rudely lenticular in shape and roughly parallel with the level beds of the limestone. They occur at various horizons, but always alongside of or near the master fault. The largest ore body was 200 by 100 feet and 60 feet thick. The ore of these great masses is all oxidized. Other ore bodies consist of impregnations of shattered or permeable rock, quartzite, or tuff, the ore passing into sulphides in depth.

There is an evident association of the ores and faulting, and a genetic relation of ore and igneous rocks.

The Old Dominion shaft is 827 feet deep (1904). The Grey mine is on an extension of the Old Dominion fault.

In the Pinal district the Black Warrior and other mines have already increased their output and are expected to become important producers in the current year.

The Saddle Mountain Mining Company, whose property is located near Gila River, close to Dudleyville and near the San Carlos Indian Reserve, has entered the list of copper producers. Its smelter was blown in in August, 1905, and is now in successful operation, treating 250 tons a day. The property of this company includes a considerable acreage that shows large areas of oxidized ore occurring in altered limestones adjacent to igneous intrusions. The development close to the porphyry contact shows sulphide ores with masses rich in magnetite, this latter ore carrying approximately 8 per cent copper present as chalcopyrite. The company is expected to produce continuously during 1906, and as the combination of garnetiferous ore, magnetite ore, sulphide ore, and limestone affords a favorable fluxing mixture, an enlargement of the plant in the near future has been confidently predicted.

The main shaft is now 330 feet deep. The ore has an average of 3 per cent copper. The product for the year 1905 was 356.8 tons of matte, carrying 394,318 pounds of copper, 90.98 ounces of gold, and 3,527 ounces of silver, with a total value of $52,124.

CLIFTON-MORENCI DISTRICT.

The copper mines of Graham County yield relatively low-grade ores, having an average value for the year 1904 of but $7.84 per ton. The Clifton-Morenci district (Greenlee and Copper Mountain districts) is the only producer of importance. The Arizona, Detroit, Shannon, Federal, and Standard companies own the principal properties, the last named being the only one not having reduction works.

The Clifton district has not shown an increase in production, owing to serious interruption by floods. Both the companies operating in this district have had construction work under way to increase the capacity of the concentrators. The Arizona Copper Company and the Detroit Copper Company both show large ore reserves.

Morenci ranks next to Bisbee as a copper-producing center, the output for 1905 being about 60,000,000 pounds. The ores now mined average between 3 and 4 per cent copper. About 20 per cent is smelting ore, carrying 6 to 10 per cent copper, and the balance is concentrating ore. The Shannon and Arizona companies, operating at Metcalf, are mining both oxidized and concentrating sulphide ores. The bulk of the ore mined is, however, a sulphide. The workings are all comparatively shallow, the deepest shaft being but 400 feet (1903).

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[a] Ransome, F. L., Geology of the Globe Copper district, Arizona; Prof. Paper U. S. Geol. Survey No. 12, 1903.

The copper deposits of Morenci and Clifton have been investigated in detail by Lindgren, from whose report[a] the following notes are extracted:

The geographical distribution of the copper deposits is practically coextensive with a great porphyry stock and its dike systems. The deposits occur either in the porphyry or close to its contacts, or along dikes of porphyry in some other rock. Areas without intrusives are practically barren. This intimate connection between porphyry and ore is as important here as it is at Cananea. The two important mining centers, Morenci and Metcalf, are situated on the main contact between a porphyry stock and Paleozoic limestones; elsewhere the porphyry adjoins granite or Cretaceous beds.

The ores consist mainly of chalcocite, malachite, azurite, chrysocolla, brochantite, cuprite, and native copper. Covellite and bornite are practically absent. Brochantite, the basic copper sulphate, is an important ore mineral present especially in oxidized veins in porphyry. It occurs intimately intergrown with malachite.

These deposits carry copper ores, gold and silver occurring only in minute quantities.

The great bodies of oxidized ores are in limestone, and occur along bedding planes and dike walls as irregular or rudely tabular masses. The ore bodies of this character which are derived by oxidation from low-grade contact-metamorphic limestones are now nearly worked out.

Both the porphyry and the contact zone about it are traversed by fissure veins, which carry pyrite with small amounts of chalcopyrite, zinc blende, and molybdenite. The principal ore mineral, however, is chalcocite, derived by secondary sulphide enrichment from the original pyritic ore.

The main output of the camp is now derived from these veins and chiefly from disseminated chalcocite occurring in the crushed and altered rock alongside of the veins, forming the so-called disseminated ore. An oxidized and almost barren zone extends usually from the surface to a depth of 100 to 200 feet. Below this occurs a zone of copper glance, which descends to a maximum depth of 500 or 600 feet below the surface. Underneath this enriched zone the original pyritic low-grade ore is found. The Humboldt is the most important vein, running northeast and southwest through Copper Mountain.

The chalcocite ores of these veins, though of low grade, are extensively worked by both the Arizona and the Detroit companies. The Coronado vein differs from the others, being a fault fissure with a 1,000-foot throw, between granite and quartzite, followed for part of the distance by a later diabase dike. There is little or no gangue mineral. The pyritic ores are contained in altered porphyry, and the upper few hundred feet of the vein contain an enriched zone with chalcocite ore.

These deposits are thus of economic importance only when secondary enrichment has taken place by the action of descending waters, and this enrichment zone is from 200 to 400 feet deep.

The Detroit Copper Company and the Arizona Copper Company are working the low-grade bodies underlying Copper Mountain, the ores carrying from 3 to 5 per cent copper and needing concentration before smelting. The mines of this character include the Humboldt, Yavapai, Arizona Central, Copper Mountain, and West Yankie. The mining costs range from $1.50 to $2 per ton. The ores are of the character mentioned above, being decomposed porphyry, with finely disseminated pyrite and glance.

Mohave County yields a small production of copper, but contains no large mines.

LESSER DISTRICTS.

Pima County has one large producer—the Imperial Copper Company, operating the Mammoth mine, formerly known as the "Old Boot." This mine is in the Silver Bell Mountains, an isolated range northwest of Tucson, having an elevation of about 3,000 feet above sea level. The ore bodies are said to be irregular lenses running northwestward in parallel shear planes. There are prominent gossan cappings, and the granite-porphyry is impregnated with copper sulphides along the limestone contact. The ores consist of pyrite, with chalcopyrite and occasional bornite, but there is also a copper-bearing silver-lead ore consisting of galena, zinc blende, and chalcopyrite, a combination difficult of reduction. The Mammoth mine is 500 feet deep and the Union shaft 350 feet deep. A railroad 21 miles in length has been built from Silver Bell to a connection with the Southern Pacific. Though the mine is equipped with a smelting plant, the production for the last year has been shipped mainly to the smelter at Douglas.

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[a] Prof. Paper U. S. Geol. Survey No. 43, 1905.

Yavapai County, which includes the Jerome district, with the famous United Verde mine and the various copper properties to the south of Jerome, has maintained its position as an important copper producer throughout the year. Unlike the other copper ores of the Territory, those of the Jerome district contain relatively high values in gold and silver. The average ore treated at the smelters had a value of $18.95 per ton, and the copper ores produced 3,854 ounces of gold in 1904. The ore body is supposed to be a columnar but wide mass of sulphides in a shear zone in diorite.

The Equator Mining and Smelting Company, whose smelter is situated 8 miles south of Jerome, was a regular producer for a few months only and is now shut down.

The Bradshaw Mountain Copper Company and the American Copper Company, with numerous adjacent properties, are in the Bradshaw Mountains district.

The results of the survey of the Bradshaw Mountains quadrangle are given in Folio No. 126 of the Geologic Atlas of the United States. The following extract from this folio relates to the copper deposits of this much-advertised region:

> No copper deposits of proved extent and value are yet known in this district, but several promising prospects were seen. Two types of copper deposit were recognized. One consists of distinct veins carrying chalcocite, chalcopyrite, tetrahedrite, and in some instances bournonite, with a gangue of quartz, fluorite, and barite.
>
> The sulphide minerals are largely altered at the surface to chrysocolla and malachite. These veins carry silver values, as well as copper.
>
> The second type consists of impregnation zones in schist, chalcopyrite, pyrite, and bornite, with more or less quartz, replaced chlorite schist or amphibolite, forming bodies of irregular and indefinite outline. Small stringer veins carrying the same minerals are also present in places, but the formation as a whole appears to be a direct replacement.
>
> The surface zones of such deposits are silicious schists, pitted and copper stained with films of native copper and sometimes of cuprite. Small gold values are also found in these deposits.

The Valverde smelter, which operates on ores from this district, was rebuilt in 1905.

The Big Bug district, also in the Bradshaw Mountains region, has a small but increasing production, and the ores contain considerable gold and silver. The 1904 production was 86.934 pounds.

Copper deposits[a] similar to those of the Kaibab Plateau[b] occur in the White Mesa, in the Navajo Indian Reservation, 125 miles north of Flagstaff and 50 miles east of the Kaibab Plateau. The Triassic red sandstone is here less than 200 feet thick and is overlain by 200 to 250 feet of white sandstone, forming the White Mesa. The white sandstone is cross-bedded. The color is white or gray, rarely red. The rock is composed of well-worn grains of quartz sand from which most of the cementing material has been leached out, leaving it soft and friable. The copper deposits consist of a replacement of the cement of one particular cross-bedded stratum of the sandstone by chrysocolla, with some tenorite in grains or masses. Specimens contain as much as 32 per cent of copper. Generally the copper deposits are a few hundred cubic feet in size, and no strict line of demarcation is shown between them and the surrounding sandstone, the bluish-green color of the chrysocolla gradually fading into the white of the sandstone. The ore is apparently associated with small vertical crevices or fissures. Some of the deposits show a distinct vein structure, while others do not. The source of the ore is not very clear.

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[a] Described by H. F. Lunt, Trans. Am. Inst. Min. Eng., 1903.
[b] Described by E. P. Jennings, Trans. Am. Inst. Min. Eng., 1903.

CALIFORNIA.

Nine out of the 57 counties of California contain producing copper mines. Their production for 1904 is shown in the following table:

Production of copper in California in 1904, by counties.

County.	Quantity.	Value.	Gold in copper ores.	Silver in copper ores.
	Pounds.			
Amador	14,000	$1,400	....	....
Calaveras	2,611,660	277,165	$74,702	$64,376
Inyo	8,408	850	50	100
Madera	10,300	1,300	....	....
Mariposa	9,500	1,140	40	20
Placer	600,000	72,000	16,000	9,120
San Bernardino	154,477	15,020	50,503	13,028
Shasta	26,438,145	3,402,517	369,813	394,590
Stanislaus	7,300	930	....	....
Unapportioned	107,800	13,700	....	....
	29,961,590	3,786,022	....	....

Two new smelters in Shasta County added to the output for 1905, while the Mountain Copper Company has built new reduction works at Martinez, on San Francisco Bay, at a cost of about $1,000,000. Calaveras County has seen the reopening of one of the most productive of the older copper mines of the State, and extensive reduction works begun in 1904 are now said to be nearly completed. Placer County gave a considerable return from the new property opened in 1904, and various other properties scattered throughout the copper belt, lying on the western flanks of the Sierra Nevada, are being equipped and developed, so that the outlook for an increased copper production is bright.

Nearly every county contains copper deposits, but the known deposits of economic importance are confined to four groups: (1) Shasta County, (2) the western flanks of the Sierra Nevada, (3) the Coast Range, and (4) the deserts of southeastern California. Up to the present time almost the entire production comes from Shasta County, in the north-central part of the State. The Foothill copper belt of the western flanks of the Sierra is nearly 400 miles long, and contains many old and formerly productive mines. One of these, at Copperopolis, has lately been reopened. The Coast Range deposits extend southward for 150 miles from the Oregon line, a number of old and formerly productive mines existing in Del Norte County.

The western or Iron Mountain belt of Shasta County lies 3 to 6 miles west of Sacramento River, between Redding and Kennett. The eastern or Bully Hill belt lies east of Sacramento River, north of Pit River, and west of Squaw Creek, near Copper City and Delamar. According to Aubury[a] the ore bodies of the western belt occur on or near the contact between granite-porphyry and metamorphic slates or schists. Those of the eastern belt lie partly in schists (Devonian metamorphic rocks), partly in porphyry, but mainly on the contact between the two.

The region has been geologically mapped by J. S. Diller, whose preliminary report on the geology of the copper deposits appeared in 1903.[b] He states that the ore deposits occur in two areas of ancient volcanic lavas, probably of Carboniferous age, mostly a metarhyolite rich in soda. The sedimentary rocks include Triassic shales and limestones in the Bully

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[a] Bull. California State Mining Bureau No. 23.

[b] Contributions to Economic Geology, 1902; Bull. U. S. Geol. Survey No. 213, 1903, p. 123. See also Bull. U. S. Geol. Survey No. 225, 1904, p. 172.

Hill district and Devonian shales and limestones in the Iron Mountain belt. The dike rocks cutting the lavas are connected with granitic intrusions and may be genetically related to the ore deposits. The ore bodies occur in shear zones, the rock sheeting and crushing being due to mountain uplift which formed the Sierra Nevada and Klamath Mountains at the close of Jurassic time. The shear zones are of limited extent, less than a mile long and from a few inches to 20 feet wide, with vertical or steep westerly dip and a north-south course.

In the Bully Hill district there are three zones, two of them parallel, a few hundred feet apart, with valuable ore bodies. The westernmost is in the Bully Hill metarhyolite; the other is a metabasalt dike near the surface, following the dike contact to a known depth of 500 feet.

The Bully Hill ore is base, carrying zinc, antimony, etc. It is said to average 8 per cent and to carry $2 to $3 in gold and silver. The ore bodies are stoutly lenticular, varying from mere nodules to masses hundreds of feet long and wide. They occur regularly distributed in the crushed and mostly impregnated rock of a shear zone 4 to 100 feet wide, averaging about 30 feet. All gradations may be seen, from unmineralized crushed rock through partial replacements and impregnations to complete replacement. The ore bodies pitch to the north. They are usually, though not always, marked by outcrops of porous limonite or gossan ore, but sometimes by merely stained rock. The gossan retains its gold values.

The Bully Hill ores consist of chalcopyrite with bornite and chalcocite, a gangue of barite, so finely disseminated as to be invisible. Copper glance is common in the dark ore. There are three lodes—the Delamar, Anchor, and Copper City. The first named is developed by a tunnel 800 feet beneath the outcrop, and the "vein" is developed for 100 feet in length. The Anchor lode is 200 feet west of the Delamar, runs N. 10° E., is vertical, and lies in silicified rhyolite, locally called quartzite. Nothing is known of the Copper City lode.

The Iron Mountain district contains the mine of the same name, together with the Shasta King and Mammoth.

The copper production of California comes mainly from the workings of the Iron Mountain mine near Keswick, owned by the Mountain Copper Company. The sulphide ores of this mine, which contain much excess iron, have long been useful as affording a means of treatment for the dry gold and silver ores of the surrounding country. The damage caused by smelter fumes, however, led to numerous damage suits, and the reduction of the ore will be hereafter accomplished mainly at the new plant, where sulphuric acid will be manufactured and fertilizer made as a by-product.

The Mountain Copper Company's ores occur as great lenses lying in schists formed by the alteration of igneous rocks. A pronounced fault separates the eastern ore body from the western. The ores consist of pyrrhotite, with pyrite and chalcopyrite and considerable zinc. The production is approximately 1,300,000 pounds of copper a year, the ore averaging about 4 per cent.

The main ore body is said to be from 100 to 400 feet wide, 800 feet long, and 500 feet deep, and was covered with gossan cappings 100 to 300 feet thick. The ore averages about 5 per cent copper, with 2 ounces silver, or slightly less than $1 per ton.

The company also owns the Hornet mine, which is in a large body of pyritic ore, carrying 2 to 2½ per cent copper, but with 47 to 57 per cent sulphur. The Bessemer copper is shipped to the New Jersey Metal Refining Works at Elizabeth, N. J., owned by the company, where the metal is refined and the gold and silver extracted. The output for 1905 was somewhat less than for previous years, owing to the construction of the new reduction plant. The ore bodies occur in northeast-southwest shear zones.

The ore has declined from an average of 7.45 per cent copper in 1897 to 5 per cent in 1901, with 2 ounces silver and less than $1 gold per ton of ore. The ore is low in silica and free from arsenic, bismuth, etc. The more northern ore bodies of this copper belt are of lower grade than those of Iron Mountain.

The Mammoth lode trends N. 80° E. and is traceable for 300 feet in length and 200 feet in depth. The dip is 30° NW. The ore is chiefly pyrite, with disseminated chalcopyrite and zinc blende, and a little quartz. It is said to be owned by the General Electric Company.

The Shasta King (Trinity Copper Company) ore body is basin shaped, with a north-south course, and is delimited by fissures. The ore carries barite locally.

The Balaklala is said to belong now to the White-Knob Copper Company. The deposit is marked by heavy gossan, and is the probable extension of the Shasta King. The ore is a low-grade mixture of pyrite, chalcopyrite, and a scanty quartz gangue. The main ore body is up to 20 feet thick, trends N. 70° E., dips northwest, and pitches northeast. The ore body is followed for 1,000 feet on the course and 500 feet on the dip.

The Spread Eagle, King Copper, and Lorraine properties are still prospects.

The Foothill copper belt is in part mapped and described in folio No. 11 of the Geologic Atlas of the United States. The chief interest in this region is in the two copper belts near Copperopolis, Calaveras County, where the Ione, Caledonia, Union, and Napoleon mines are found. The ore consists of chalcopyrite and quartz. The Napoleon-Camp Seco lode lies 3 miles west of the Copperopolis lode. At the Union mine the lode is a vein of black pyritous slate in a belt of amphibole schist, identical in age and character with the Mother Lode vein, 12 miles to the east. The Ione and Caledonia, with the Copperopolis mine, occur in a similar belt in the schist area just east of the western belt of Mariposa slates.

The Copperopolis vein is 3 to 40 feet wide. The Union or Keystone mine has an average width of 15 feet and carries a chain of lenticular masses of chalcopyrite, connected by ore stringers. Three ore bodies have been worked, the largest, at the Union mine, being 2 to 40 feet wide, 300 feet long, and 600 feet deep, and pitching to the north.[a]

The ore carries no gold or silver, and is exceptionally pure, varying from 3 to 5½ per cent, with some 11 per cent smelting ore. The property is 14 miles from a railway and 40 miles from tide water.

The second, or Camp Seco belt, contains the mines of the Penn Chemical Company, on Mokelumne River, 20 miles northwest of Copperopolis. The vein contains chalcopyrite and pyrite, with a trace of zinc and low values in gold and silver, in a gangue of talcose schist, clay, and quartz. A quartz-porphyry dike accompanies part of the vein. The deepest development is by a 550-foot shaft at the Union. A 100-ton pyritic smelter is intermittently in operation.

The Napoleon, the oldest copper mine of the State, is 9 miles southwest of Copperopolis. The vein channel is 100 feet wide, and consists of diabase and metadiabase down to talcose schist. The dip is 62° and the vein is developed to 250 feet in depth.

At Copperopolis the smelter was blown in during December, but closed for three weeks during January. The ore supplied is derived from the Copper King mine, but as the smelter is 15 miles from the railroad and the fuel is oil, hauled by traction engine, it was obliged to shut down on account of the bad roads.

COLORADO.

Colorado has few producing copper mines. The copper output is obtained mainly as a by-product of the precious-metal ores treated in custom smelters. The production comes from eleven different counties, one-third of it being, however, from Lake County. San Juan County is the next largest producer. At Pearl, an extension of the Encampment, Wyo., district, a small matte smelter erected in 1904 is idle and the property unproductive.

The production by counties for 1904–5 is given in the following table:

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[a] See Copper Resources of California; also Mother Lode district: Geologic Atlas U. S., folio 63, U. S. Geol. Survey, 1900.

Production of copper in Colorado, 1904-5, by counties.

County.	1904.	1905.	County.	1904.	1905.
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*
Boulder	5,340	14,106	Larimer	3,780	4,336
Chaffee	456,556	869,507	Ouray	431,048	524,199
Clear Creek	369,778	355,740	Park	....	38,374
Custer	10,910	862	Pitkin	2,908	127,094
Dolores	12,201	71,122	Saguache	48,066	2,988
Eagle	27,042	65,179	San Juan	3,575,219	2,274,106
Gilpin	604,791	638,597	San Miguel	245,709	272,513
Gunnison	1,864	36,997	Summit	....	44,033
Hinsdale	10,530	24,532			
Lake	3,627,846	4,486,117		9,435,962	9,850,827
La Plata	2,374	425			

The smelter returns for 1905 indicate that the production of copper from Colorado amounted to 10,736,151 pounds for that year. This is after the product of other States has been excluded from the smelter returns. The greatest return is from the American Smelting and Refining Company, which had an output of 8,920,064 pounds, of a value of $1,382,750.

GEORGIA.

The copper product of Georgia is at present insignificant, amounting to 8,841 pounds in 1905, in the gold and silver bearing matte from the Seminole or Magruder mine in Wilkes County. This deposit was described by the writer in Bulletin No. 225, pages 180-183.[a]

The Ducktown (Tenn.) copper belt extends southward into Fannin County, Ga., where the Sallie Jane, Lot No. 20, and Mobile mines were worked many years ago. The second named has recently been reopened. The mine is about 4 miles south of Isabella Ferry, between Pierceville and Frytown, Ga. It is owned by J. T. Howe and is worked under the superintendence of John Quantrell. The development consists of a shaft 100 feet deep, with a drift driven 200 feet to the east and 900 feet to the west. At the end of the east drift there is a winze 100 feet deep, with a second drift 100 feet long at the bottom. These workings show the vein to average 20 feet in width. The ore is said to carry from 3 to 30 per cent of copper. In the upper levels green carbonates are found, with the usual black ore near the water level and the gray and so-called yellow ore below. The presence of feldspar in the ore is notable. No ore has as yet been smelted or shipped. The information concerning this property has been furnished by Mr. L. La Forge.

IDAHO.

The copper production of Idaho for the past three years is as follows: 1903, 569,480 pounds; 1904, 4,518,034 pounds; 1905 (official), 6,661,400 pounds. This production comes from six counties—Bannock, Boise, Custer, Lemhi, Shoshone, and Washington. The Snowshoe mine in Shoshone County is the chief producer, the balance coming mainly from gold-silver properties. Fremont County yielded copper ore in 1903, but not in 1904. The Washington and Custer county (Loon Creek and Alden Creek) districts yielded gold-bearing copper ores. The Cœur d'Alene ore goes to Butte and Tacoma smelters; that of the other counties is reduced in furnaces in other counties.

In the Fort Hall mining district, Bannock County, the Pocatello Gold and Copper Mining Company is working a "well-defined fissure vein carrying disseminated bornite." In 1904 ore was shipped to the copper smelters of Mackay and Salt Lake. The Fort Hall

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[a] Contributions to Economic Geology, 1904.

Mining and Milling Company has driven a crosscut tunnel 2,500 feet long to cut an auriferous copper vein.

Boise County produced but 500 pounds of copper in 1904, as a by-product of gold ores shipped to custom smelters.

Custer County was formerly the largest copper producer of the State, the production for 1904 being 2,734,489 pounds, valued at $341,811. This came from the mines of the White Knob Copper Company, of the Alden Creek district, now shut down, and from the Loon Creek district. The production for 1905 was 684,134 pounds.

The White Knob ore deposit[a] occurs on a contact between granite and limestone. The ore zone is 400 feet wide and 1,200 feet long, and contains chalcopyrite, pyrite, and a little galena, together with magnetite and hematite in an altered limestone composed of garnet and calcite. The oxidized zone is 600 feet deep. The White Knob smelter was shut down in 1905. Recent development has shown the existence of payable bodies of sulphide ore beneath the ore oxidized zone and the mine is again actively worked.

An important development of copper ore has been made at Loon Creek, where the Lost Packer Mining Company owns a fissure vein in granite and rhyolite. The vein is 10 to 15 feet wide and carries a pay streak about 2 feet wide that is clean and well defined. The ore consists of massive chalcopyrite, with 20 per cent of copper and about 2 ounces of gold. Outside of the pay streak the vein is of low grade, running, it is said, about 3 per cent of copper and $5 to $7 gold. A blast furnace capable of handling 100 tons daily has recently been installed.

The Paymaster copper mine, in the Skull Canyon district, Fremont County, works a deposit on a contact between limestone and quartzite.

Lemhi County produced about 5,000 pounds of copper in 1904, occurring in gold and silver ores.

Shoshone County produced 5,805,000 pounds of copper, of a value of $893,389, in 1905.

The only productive copper property of the Cœur d'Alene district is the Snowstorm mine, east of Mullan. The deposit occurs in Algonkian (Revett) quartzite, and is, according to Ransome, an impregnated cupriferous zone conforming to the bedding planes, the strike being N. 60° W. and the dip 65° SW. The ore body varies from 10 to 35 feet in width, and is reported to be 430 feet long. The ore carries chalcopyrite, bornite, and chalcocite in disseminated particles in the quartzite. The quartzite is not particularly fissured and does not appear to differ from the rock of the foot and hanging walls. The greater part of the mineralized quartzite contains about 4 per cent of copper, with 6 ounces of silver, and 0.1 ounce of gold per ton. The ore shipped is worth $9 to $10 per ton, the Butte and Tacoma smelters giving a freight and treatment rate of $5 when $SiO_2=90$ per cent. A leaching plant is reported to have been erected on the property in 1905.

Washington County produced 898,209 pounds of copper in 1904, valued at $112,276. This output came from the Seven Devils district, the Landore smelter of the Ladd Metal Company and the smelter at Sumpter, Oreg., treating the ore. The chief producing mines are those of the Blue Jacket Consolidated Copper Company and the Montana-Nebraska Copper Company, but small amounts were also produced by the Peacock, White Monument, Helena, Queen, Alaska, and Crescent. According to Lindgren, the ores occur as follows:

> In the Seven Devils district and in the adjacent Snake River canyon copper deposits are very abundant. There is, in that vicinity, an extensive series of Triassic basic lavas, with intercalated layers of slate and limestone. There are also diorites, intrusive in these beds. All of these igneous rocks apparently contain copper which was easily concentrated into deposits of various kinds—some fissure veins, others zones of impregnation, others contact deposits.
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> In the locality of the original discovery in the Seven Devils the copper occurs in typical contact deposits. Small masses of limestone are embedded in a later, intrusive diorite; at the contact and usually in the limestone are found irregular bodies and bunches of bornite, chalcocite, and a little chalcopyrite, containing about 10 ounces of silver and a little gold per ton. The limestone at the contact is very crystalline and contains, associated with the ores, abundant garnet, epidote, quartz, calcite, and specularite. The copper sulphides, as shown by their intergrowth, were certainly formed at the same

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[a] Lindgren, W., Character and genesis of certain contact deposits: Trans. Am. Inst. Min. Eng., 1901.

time as the gangue minerals. The epidote, specularite, and garnet, as described by Palache,[a] present clear evidence of simultaneous crystallization. At the Peacock mine a large body of medium-grade ore of this character was embedded in diorite. No limestone showed here, but I am informed that a lower tunnel has lately encountered limestone below the croppings.

Other claims in which the ore occurs on the contact of limestone and diorite are the White Monument, Alaska, Blue Jacket, Helena, and Decorah. Considerable masses of ore have been exposed at some contacts, though the distribution is extremely irregular. In the Blue Jacket a rich body of bornite and chalcocite was lately found, and it is reported that 500 tons of 40 per cent ore has been shipped from this mine during the past summer. During 1900 the Boston and Seven Devils Copper Company shipped from the Peacock and other claims 260 tons containing 23 per cent of copper besides 8 ounces of silver and 0.04 ounce of gold per ton.

Still another copper deposit in Idaho which appears to belong to this type is the White Knob mine, near Houston, in Lost River Valley. Mr. W. Darlington, the general manager of the company, has kindly furnished the following information: The ore occurs as a deposit between granite and limestone; the trend of the contact is north and south, the limestone lying to the east and the granite to the west. On the surface the ore-bearing zone is 1,200 feet in length and (as a maximum) 400 feet in width. The minerals are hematite, magnetite, chalcopyrite, pyrite, and a little galena, in a gangue of garnet and coarsely crystalline calcite. A porphyry dike also occurs on the contact, complicating the geological relations. The oxidized zone is very deep, water not having been encountered until the depth of 600 feet was reached in the shaft.

MICHIGAN.

The Lake Superior copper district has shown a larger production for 1905 than at any time in its previous history. There were nineteen regular producers, and the output for the year is estimated at 220,950,000 pounds, valued at about $35,000,000, an increase of nearly 12,600,000 pounds over that of the preceding year. As usual, the largest output and largest gain is made by the Calumet and Hecla Company, which furnished nearly 27 per cent of the total production for the year, the chief production coming from the "Calumet conglomerate," as in former years. The "Kearsarge amygdaloid belt" has also furnished part of the Calumet production. The only new producer is the Allouez, the ore from this mine being treated in the Centennial stamp mill. The Copper Range properties were extensively developed, insuring an increased output for the current year. Among the older properties there has been a marked revival of interest and many of the mines are now being reopened, owing to the high price of copper. Among the producers which may be expected to add to the output of the district in the near future may be mentioned the Keweenaw Copper Company, which is under the control of the Amalgamated Copper interests. The Resolute, owned by the same interests; the Delaware, recently purchased by the Calumet and Hecla; and the Cliff, owned by the Tamarack Company, have also been extensively developed during the year. The Erie-Ontario Development Company and the King Philip Mining Company are among the newer ventures. The Phoenix is the only mine abandoned, as the St. Clair vein proved too narrow to permit profitable working.

Eight mines paid dividends, the total being $9,014,600, of which $5,000,000 was paid out by the Calumet and Hecla.

The Lake Superior district is unique among the copper regions of the world. Somewhat similar deposits occur in other places, but they are small and as yet unworked. The copper occurs in a native state, and the extent of the ore-bearing beds, the nearly uniform dip of the beds, and the fact that the copper is present for long distances along a bed render mining a stable industry in this district. These conditions and well-established systems of transportation for ore and supplies permit such cheap mining that ores containing less than 1 per cent of copper are worked at a profit. The dividends paid by the different mines operating this district aggregate about $160,000,000, and are greater than those of any other mining district in the world. The annual production is about 15 per cent of the copper output of the world. The mining companies in operation are increasing their output year by year and new mines are being developed, and yet it may be confidently asserted that there is no present sign of exhaustion of the region.

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[a] Am. Jour. Sci., 3d ser., vol. 8, October, 1899.

GEOLOGY.

The Keweenaw Peninsula, the site of the copper mine of Lake Superior, is 40 miles across from east to west and projects about 70 miles northeastward into the lake. The central portion of this peninsula is formed of a succession of lava beds interbedded with layers of sandstone and conglomerate. The lavas are of two kinds, the prevailing variety being a dark basaltic rock, having the texture of diabase and most conveniently designated as trap. The light-colored lavas are quartz-porphyries or rocks corresponding to andesite in composition. The conglomerates are composed of rounded fragments of igneous rock, the light-colored reddish-chocolate and yellowish quartz-porphyries predominating. The entire series has a thickness of from 25,000 to 30,000 feet and is flanked on both sides by conglomerate and sandstone. To the west these sediments appear to be conformable, dipping with the lava beds. To the east there is a fault and the sandstones are nearly horizontal.

Copper occurs native in these rocks. It was first found in fissures cutting across the rocks and later in veins which cut the bedded series at an acute angle to the dip. At the present time, however, the great production of the region comes from the amygdaloidal lava beds and the so-called "ash beds" of nearly similar character and from the copper-bearing conglomerate, the latter rock furnishing one-half of the total production.

The so-called "Copper Range" is a belt from 4 to 6 miles wide, lying on the eastern side of the series of bedded trap rocks. The different members of this series vary from a few feet to 100 feet in thickness. the individual lava flows or layers being distinguished by the amygdaloidal or vesicular nature of the upper portion and in many cases being separated by beds of conglomerate. The igneous rocks have been altered to dark-green rocks in which the original hornblende and augite have become chlorite and epidote and the holes or vesicles have been filled by quartz, calcite, and other minerals, including native copper Both the amygdaloids and the conglomerates are heavily impregnated with epidote. The copper occurs in crystalline form and as casts or fillings having the shape of the amygdule which it fills. The conglomerates often inclose seams of fine-grained sandstone, but in such cases the copper impregnation is confined to the conglomerate. The conglomerates consist largely of chocolate-colored and reddish porphyry, with a few fragments of diabase and amygdaloid. These beds outcrop as ledges having a general northeasterly course, but owing to glacial erosion and the covering of the country by drift long outcrops are seldom seen and exploration work consists largely in stripping off the superficial cover to find the underlying trap beds.

The chief ore production of the district comes from the "Calumet conglomerate." This bed is from 12 to 25 feet thick, and has a northwest dip of 36° to 39°. The ore is not continuous throughout the entire extent of the bed, but is confined to ore shoots of great length; thus the Calumet and Hecla property is productive for 2 miles in length, and in this distance there are but few lean spots.

The diabase beds have the characteristics of extrusive lava sheets whose upper surface is often scoriaceous, giving rise to the term "ash bed." In the uplifting of this great series of trap rocks there has been dislocation, and cross veins have been formed.

The distribution of the copper in the different ore-bearing beds is dependent on the structure of the rock. In the Quincy mine the hanging-wall rock is richest, this portion being the most permeable. In the Atlantic ore bed the copper is somewhat uniformly disseminated throughout the amygdaloid. In the Baltic mine the copper is irregularly distributed and the ore channel appears to be a sheared zone, the fracturing extending beyond the limits of the amygdaloid layer and into the incasing trap. Slip planes and flat cross joints indicate movements, a cross vein at No. 4 mine extending for 200 feet across the beds, and carrying copper with quartz and calcite. Cross veins, though frequent, do not extend beyond the limits of the ore bed and conform in strike to that of the main ore bed. The occurrence of copper in these cross veins and of sheet copper along cross joints in the foot wall indicates migration of material after the original ore deposition was completed. Lump copper is common and can often be recognized by the light-colored patches of decomposed rock surrounding it.

Joints and long slip planes are of frequent occurrence and may mark a change in the copper content, the rock on one side being richer or poorer. As a rule the cross courses consist of bands from a few inches to 2 feet wide of crushed rock seamed with white calcite. They dislocate the copper lode but slightly and seldom contain copper. In general, the mineralization of the amygdaloidal lodes is diffused and irregular and the richer rock lies against the hanging wall.

The conglomerate lodes have been the richest in the history of the region. The bed known as the "Allouez," or as the "Albany and Boston conglomerate," is from 8 to 25 feet thick. It is underlain by 3 or 4 feet of sandstone, resting in turn upon trap rock, and it is overlain by a foot of clay gouge with 4 to 5 feet of shattered trap rock above it, and then the normal hard trap rock forming the hanging-wall bed. Like the amygdaloid, the conglomerate is also traversed by well-marked joints and slips. The pebbles range in size from a pigeon's egg to bowlders as large as a man's head. The rock composed of smaller pebbles is more favorable for copper, and the best ore occurs where the cementing material is less firm, the copper favoring the permeable rock. In the Franklin mine the foot-wall sandstone thins out in depth, and the copper extends from the conglomerate into the underlying amygdaloid. The dip is about 18°. The ore-bearing beds sometimes lie close together; for example, the "Osceola conglomerate" lies 800 feet east of the "Calumet conglomerate."

A knowledge of the geology of the region is essential to successful prospecting. The trap beds are so nearly alike that identification is ordinarily impossible, but occasionally some mineralogical characteristic will serve as a guide, as, for example, the foot wall of the "Kearsarge amygdaloid" is a bed marked by large feldspars. Usually the amygdaloid layers weather more readily than the compact trap incasing them, and hence show infrequent exposures and are covered with drift and soil. The conglomerate beds resist erosion and form occasional outcrops.

DEVELOPMENT.

The following lodes are worked: The Calumet conglomerate is developed by the Calumet and Hecla Company. The Kearsarge amygdaloid, which lies 2,130 feet east of the Calumet and Hecla conglomerate, is worked by the Calumet and Hecla, the Allouez (on the underlay), the Akmeek, and the Tecumseh companies. The Franklin and Rhode Island companies are both trying to locate ore in this lode. The Osceola amygdaloid, which lies 2,200 feet east of the Calumet conglomerate, is worked by the Calumet and Hecla Company and the Tamarack Company. The Baltic lode is worked by the Superior, the Baltic, and the Tri-Mountain companies, and has been prospected by the Rhode Island Company, but proved too lean in their ground to yield a profit. The ore in this lode is spotty, good ore alternating with lean. The Pewabic and Allouez lodes have proved too lean to work in the Rhode Island Company ground. The Knowlton and Butler lodes are worked by the Mass Copper Company. The Montreal River lode is worked by the Keweenaw Company, and the Calumet and Hecla Company is reopening the old Manitou property near Lac la Belle.

MONTANA.

The copper production of Montana continues to dominate the entire industry, amounting to the enormous total of 335,000,000 pounds in 1905. Although for many years past this State has furnished about 40 per cent of the copper production of the United States, it will not quite reach this figure for 1905, as the increase in Arizona has been extraordinarily rapid. The production of the State is almost entirely from the Butte mines, but a small amount is reported from Beaverhead County, mainly from the Indian Queen mine, and from Meagher, Jefferson, and Madison counties, these four counties yielding gold-copper ores. The copper ores of Montana furnish 18 per cent of the gold production of the State and 80 per cent of the silver production. The gold-copper ores of Beaverhead, Meagher, and Jefferson counties furnish a total of 17,300 ounces of silver out of a total of 10,250,000 ounces.

The statistics of the 1905 production of copper for the individual counties are not yet available; those for 1904 are as follows:

Production of copper in Montana, 1904, by counties.[a]

	Copper.		Gold in copper ores.	Silver in copper ores.
	Mint report.	U. S. G. S. report.		
	Pounds.	*Pounds.*	*Ounces.*	*Ounces.*
Beaverhead County	68,815	543,126	31.15	12,577
Meagher County	....	75,000	50.00	2,000
Jefferson County	161,100	11,100	4.00	2,750
Lewis and Clarke County	17,067	7,067	....	....
Madison County	15,815	11,300	465.25	....
Powell County	30,000	1,000	....	....
Silverbow County	283,070,422	290,032,979	43,889.90	10,218,792
Miscellaneous	587,111	....	....	....
Total	283,945,330	290,681,572	44,440.30	10,236,119

[a] The figures in the last three columns are from the chapter on Gold and Silver Production of the United States in Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905. They differ materially from those of the Director of the Mint in his report on Precious Metals of the United States for 1904, p. 139, as shown in first column.

It will be seen that Silverbow County, according to these figures, yielded 99½ per cent of the copper product of the State.

GEOLOGY.

The geology of the Butte copper district has been somewhat fully presented by the writer in a previous bulletin (No. 213), and in Folio No. 39 of the Geologic Atlas of the United States. The main facts are as follows:

The Butte district is in southwestern Montana, in the central part of the Rocky Mountain region, within 2 miles of the continental watershed. The rocks of the region are all igneous, the prevailing form being a dark basic granite, or quartz-monzonite,[a] which is part of a great mass of granite forming the core of the mountainous area extending from Butte to Helena. This rock is cut by irregular and dike-like bodies of a lighter colored granite rock—an aplite called the "Bluebird" granite, largely used for building stone at Butte. This rock covers relatively small areas on the surface, but is more abundant in deep workings. Both the granites mentioned are cut by the "Modoc" porphyry, a light-colored quartz-porphyry, carrying large and well-formed crystals of quartz. The latest rocks are rhyolitic in nature and later than the veins in age.

The veins occur in the basic or Butte granite, but cut through the other rocks. They can be grouped into silver veins and copper veins, and the two classes occupy distinct areas, with but little overlapping. The copper area is about one-half mile by 1½ miles in extent.

The veins belong to four distinct systems. The largest veins, embracing the Anaconda and its dislocated segment the Parrot, the Syndicate ledge, and, in fact, all the greatest producers of the district, run east and west, and dip steeply to the south. These veins are faulted and displaced by a northwest-southeast series, including the Clear Grit, Blue, Skyrme, Gray Rock, and other important veins. A still later set has a direction east of northeast, and faults and displaces both the earlier vein systems; the veins of this set are in places heavily mineralized, as in the Stewart mine. The latest fracturing is by northeast-southwest faults which contain drag ore, but little if any newly formed ore.

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[a] Granite Rocks of Butte, Montana, and vicinity: Jour. Geol., vol. 7, 1899, pp. 737-750.

The older veins are distinctively replacement veins, and consist of quartz and pyrite with secondary glance ores. They are surrounded by areas of granite altered by solfataric action.

The output consists of glance-pyrite-quartz ores, often of high grade, and of the altered granite impregnated with glance and pyrite. The bulk of the material mined is concentrating ore, carrying 3 to 4 per cent of copper, 55 per cent of silica, and 16 per cent of iron. Many of the lesser veins in the eastern part of the district consist of nearly solid enargite and pyrite. The Parrot and Original ores carry much bornite. The ores contain silver, the quantity varying from 1 ounce to 1 per cent of copper in the Trenton to one-fourth ounce to 1 per cent in the eastern part of the district. The ores average about 0.0375 ounce silver and $2.25 per ton of gold. The veins carry high-grade ores to exceptional depths. The Anaconda carries rich glance ore at 2,200 feet; the Original has enargite-bornite-glance ore at 2,000 feet; the Diamond, Mountain Con, and High Ore at 2,000 feet.[a]

DEVELOPMENT.

During the year 1905 the copper output for Montana reached the enormous total of 335,000,000 pounds. With the exception of a small production from scattered properties, this great output comes from the copper mines of the Butte district. During the year several important discoveries and developments have been made. The Pittsburg and Montana Copper Company, operating in the flat between the city of Butte and the East Ridge, has opened up four veins on the 1,200-foot level, and is now producing 5,000 tons of ore a month, and the furnaces are producing copper from the company's own ores. This company has, it is understood, abandoned the attempt to use the Garretson process, and is smelting its siliceous Butte ores with pyrrhotite from the Spring Hill mines situated south of Helena. In converting the matte raw siliceous ore is charged directly into a molten matte (Baggally process), a basic lining to the converter being used. This is a marked change from ordinary practice, in which siliceous linings are used.

The discovery of these veins in what has hitherto proved a barren portion of the district has greatly stimulated activity in the vicinity of the mines. Several new companies have been formed to take over properties in this part of the district, and active exploitation is promised in 1906.

The North Butte Copper Company was formed during 1905, and acquired the Speculator, Edith May, Jessie, and other properties. A crosscut driven north developed ore bodies of phenomenal size and richness in the Edith May and Jessie veins. These ore bodies mark the farthest known limit of the rich copper ores of the district, and, as noted later, occur under conditions which have awakened widespread interest in the possible extension of the copper-bearing zone to the north. In the western portion of the copper-producing section the Lexington mine, now controlled by the United Copper Company, has yielded considerable high-grade copper ore, but this has been of a different character from the ore of the copper belt, consisting mainly of chalcopyrite, an unusual mineral in the copper mines proper.

The Raven mine, which lies north of the Buffalo and is in the extreme northwestern part of the copper belt, has also yielded considerable amounts of copper ore, and the Snoozer claim of this company is being extensively prospected and developed from the crosscut on the 1,500-foot level driven from the Buffalo shaft.

In the great mines of the camp the workings have been deepened, with marked success. The most notable instance is in the Anaconda mine, where the shaft has been deepened to 2,400 feet and the crosscut from the 2,200-foot level encountered rich ore on the middle ledge. This "strike" has been widely heralded in the newspapers. On the 2,400-foot level the crosscut had not reached the vein at the beginning of 1906.

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[a] See description in Nature of Ore Deposits, a treatise on the Ore Deposits of the World, by Beck and Weed, p. 223.

In the other properties belonging to the Anaconda Copper Company production continues at an increasing rate, and development work thus far shows little change in conditions during the past year.

In the Boston and Montana properties the deeper levels have shown an ore body maintaining the full width encountered above, and tetrahedrite has been found in some of the ores, with an accompanying rise in gold values.

In the mines owned by Hon. W. A. Clark development work has been extremely fruitful, and the ore bodies have proved even larger and richer than they were in the upper levels. The Stewart shaft has been dismantled and abandoned, and the workings of this mine are entirely from the new shaft formerly known as the West Stewart, but now commonly called the Stewart. This shaft is 1,800 feet deep, and the ore body on the lower level is said to show 20 feet of ore, carrying 12 per cent or more of copper, developed for a distance of 400 feet in length.

In the Original mine the shaft is 1,800 feet deep, and on the 1,800-foot level an ore body 25 feet wide, said to average 18 per cent of copper, has been drifted on for 150 feet and its limit not yet reached.

For many years past this great copper camp has been stirred by litigation and the conflict incident to attempts to control the politics of the county. But few companies were formed and their success was doubtful. Within the last six months, however, many new companies have sprung into existence and the end is not yet in sight. This is probably largely the result of the boom in the price of copper and copper stocks, but it is also due in a great degree to the phenomenal success of the North Butte Company in developing the largest and richest ore bodies found in recent years. Among the older of the companies formed in the last few years is the Pittsburg and Montana Company, which has at last reached the production stage, its output now being about 300,000 pounds of copper per month from the company's own ores. But one blast furnace is run.

The Reins Copper Company, owning property east of the Boston and Montana, has opened up a good vein of copper ore on the 800-foot level, has sunk a shaft to a depth of 1,070 feet, and will cut a station at the 1,200-foot level in the near future. Though fairly rich ore has been encountered in this property, no stoping has yet been done and some difficulty has been experienced in handling the flow of water.

Among the newer companies organized may be mentioned the Butte and London Copper Company, which will develop the Greendale placer, north of and adjoining the Pittsburg and Montana ground.

The East Butte Company has bought up and is now mining ore from a number of small claims and city lots in the southern portion of the city.

The Columbia-Butte Company, controlling four claims in the copper-silver belt west of the Lexington mine, is reported to have found a 10-foot vein of ore carrying one-half to 1 per cent of copper on the Jennie Dell claim, at a depth of 358 feet, supposedly on the Lexington vein.

The owners of the Raven property, which has been extensively developed during the past three years, have incorporated the Raven Mining Company. The property owned by this company consists of the Raven and Snoozer claims, and is being developed at a depth of 1,500 feet by a crosscut from the Buffalo shaft of the Amalgamated Company. The Raven has been shipping ore for some years.

The J. I. C. mine is now being developed by the Amalgamated Company, as is also the Greenleaf claim, lying east of the flat, near the Great Northern tunnel.

The Berlin mine has recently been acquired by the North Butte Company, and work on the 400-foot shaft has been stopped, as the future development will be carried on from the deep levels of the company.

The United Copper Company is operating the Belmont and Glengary mines, the Belmont shaft being reported to have a depth of 900 feet and the Glengary of 800 feet. The Dutton shaft of the East Butte Company is to be sunk from 350 to 1,000 feet in depth.

The total production from the district is now approximately 15,500 tons a day. The Amalgamated Company is treating 8,350 tons a day at the Washoe smelter, of which 1,000 tons is North Butte ore and 550 tons from the W. A. Clark mines. This is the largest quantity treated at any individual copper plant in the world, the Calumet and Hecla Company coming next in point of production, with a daily treatment of 6,000 to 7,000 tons of ore. The Great Falls smelter, also belonging to the Amalgamated Copper Company, treats 3,700 tons a day. The properties belonging to Senator Clark yielded about 2,000 tons a day, treated partly in his own works and partly by the Amalgamated Company.

The Butte Copper Exploration Company, controlling eight claims east of the city, has begun development. The Golden Chief is reported (in the Engineering and Mining Journal) to show a 30-foot vein of 2½ per cent ore.

Daily and gross output of Butte copper mines, December, 1905.[a]

Mine.	Daily tonnage.	Pounds of copper per ton.	Pounds daily.	Tonnage for month.	Pounds for month.
Boston and Montana	3,100	73	226,300	96,100	7,015,300
Anaconda	4,125	64	264,000	127,875	8,184,000
Butte and Boston	530	63	33,390	16,430	1,035,090
Trenton	600	62	37,200	18,600	1,153,200
Washoe	420	68	28,560	13,020	885,360
Parrot	400	70	28,000	12,400	868,000
Clark's Original	1,250	72	90,000	38,750	2,790,000
Pittsburg	160	82	13,120	4,960	406,720
North Butte	625	138	86,250	19,375	2,673,750
United Copper	1,615	69	111,435	50,065	3,454,485
East Butte	180	160	28,800	5,580	892,800
Miscellaneous	400	65	26,000	12,400	806,000
	13,405	....	973,055	415,555	30,164,705

[a] Mining World, Jan. 27, 1906, p. 145.

NORTH CAROLINA.

The copper production of North Carolina amounted to 700,000 pounds in 1905. This comes almost entirely from the mines of the Virgilina and Gold Hill districts.

In the Virgilina district the ores consist of bornite and copper glance in a gangue of white, coarsely crystalline quartz. The ore is sorted, the high-grade material being shipped and the low-grade ore treated in a concentrating mill. The mines owned by Person Consolidated Copper and Gold Mines Company were the only ones in operation in 1905.

The actual value of the Virgilina properties is dependent on several variable factors, the most important being, of course, the price of copper. The ores occur in a very hard quartz and carry from 70 to 80 per cent excess silica, while the copper minerals, though free, are extremely brittle. Wet concentration effects a saving of about 50 per cent of the value, and on a 2 per cent ore, with only an ounce or less of silver, is clearly unprofitable. Hand picking has been practiced at several mines, but is hardly profitable.

The cost of mining in this district is estimated at $1.75 to $2.25 per ton, including 35 to 65 cents per ton for development work. With these figures the problem of profitable working is one of freight rates to a smelter. Assuming a 2 per cent ore and copper worth 15 cents a pound, the gross value, including silver contents, is $6.50. Deducting $2 for mining costs leaves $4.50 for freight, smelter charges, and profit.

In Rowan County the Gold Hill district produced 840,000 pounds of copper in 1905 from the Union Copper Company mine. The property shows a number of well-defined veins of the usual Appalachian "schist" type, with gold values in the oxidized ore. The copper ore occurs in shoots and consists of chalcopyrite intimately intergrown with quartz. Concentration is not effective owing to the fineness of the particles of chalcopyrite and the practical impossibility of a clean separation. The ore is highly siliceous and carries a low precious-metal content. One workable ore shoot has been developed in the Union Copper Company's workings, and this is open to a depth of 800 feet. The ore is shipped to New York, and to Ducktown, Tenn.

Besides the two districts mentioned North Carolina has many copper-bearing veins in the gold belt lying along the boundary between the old Algonkian (?) slates and the granite mass. The Crosby and Concord Hill mines, near Concord, are among the best known, the ore being chalcopyrite associated with siderite (carbonate of iron).

In the mountain region of Jackson County there are several copper veins, formerly worked, that carry copper pyrite. They are in metamorphic schists but usually occur associated with amphibolite bands. The only property recently worked is the Cullowee (Davies post-office), near Sylva, on the Murphy branch of the Southern Railway. The ores consist of chalcopyrite in a quartz gangue, occurring in a band of amphibolite. The development work on the various properties is not sufficient to warrant an estimate of the importance of the veins as future producers. The ore shoots so far known are not large, and though the veins are often traceable by their iron-stained outcrop for a mile or two, development work is limited to a few points. These properties are at present several miles from the railways, but branch lines could be easily and cheaply constructed and would serve the timber and clay industries as well.

The Rowan and Salisbury copper mines have been worked to some extent and the Mead mine has been developed.

NEVADA.

Nevada has as yet only a small annual production of copper. Six counties yielded a total of 29,317 pounds of copper in 1904, the largest production, 13,963 pounds, coming from Eureka County.

Elko County produced 7,200 pounds in 1904, from the high-grade gold-bearing ores of the Weston and Frank mines, in the Railroad district.

Esmeralda County gave the small amount of 300 pounds in 1904. The Sodaville copper belt occurs in this county, at the north end of the Pilot Mountains, about 18 miles east of Mina, a new town on the Carson and Colorado Railway. The copper ores occur in a contact zone 12 miles long, on the borders of a granite intrusion. On the east side of the range the Dunlap property is being developed by the Guggenheim interests. At the north end the copper-contact mine is shipping small amounts of ore, and at the south end the D'Arcy mine is also producing. On the west side of the mountains the Utavarda Copper Company, at Garnet, shows a vein said to be 13 feet wide, opened by a 70-foot shaft and proved for 2,700 feet horizontally.

Eureka County yielded 13,963 pounds, of a value of $1,380, mostly from the Tenabo Mining and Milling Company's mine in the Cortez district.

Lander County yielded 3,200 pounds of copper in 1904.

Nye County produced but 70 pounds of copper, from the gold-silver ores shipped to smelters.

White Pine County, whose great ore bodies are now being so actively and extensively developed, yielded but 4,584 pounds of copper in 1904. Within the last few years a great mining district has been quietly developed in this county, and its mines will soon take high rank among the world's great producers. The region, commonly known as the "Ely district," lies 6 miles west of Ely, the county seat, which is 140 miles distant from Toano, a station on the Southern Pacific Railroad. The place is officially known as the "Robinson mining district."

The mineral-bearing area consists of shales and limestones, intruded by an immense dike-like mass of monzonite-porphyry that is traceable for some miles in length, with a later intrusion of rhyolite-porphyry transversely cutting across the porphyry in the center. On the northwestern border of the field an intrusion of granite occurs cutting the monzonite. The mineral-bearing porphyry is a white siliceous rock, with a brown weathered surface. In places it is so silicified that it forms hard masses which stand out in relief above the more gentle slopes of softer, leached rock.

The ore bodies are of enormous extent. That of the Eureka mine is 70 by 800 feet, and has been developed to a depth of 100 feet. That of the Ruth mine has a width of 50 to 250 feet, is developed for 400 to 900 feet in length, and has a known vertical thickness of 250 feet. According to Channing, from whose report on the Nevada Consolidated Copper Mining Company's properties these notes are taken, the rock is leached for 50 to 100 feet down, carrying not over one-half of 1 per cent of copper. Below this the ore is white and soft, and consists of decomposed porphyry carrying minute seams of pyrite and copper glance, with some quartz. This is typical "disseminated" ore, exactly analogous to the ores of Morenci and Bingham. At the Ruth mine there is a 640-foot inclined shaft, having an angle of 41°, equal to 420 feet vertical. Levels are driven at 200, 300, 500, and 650 feet on the incline, and the ground is blocked out by 200-foot crosscuts. The ore has a content of 2.6 per cent of copper at the Ruth mine and of 2.2 per cent of copper at the Eureka mine, with 40 cents per ton in gold. A large concentrating plant has already been planned, and with the completion of the railroad now being built by the company the property will have an estimated output of 3,000 tons a day. It is expected that a saving will be made of 77 to 79 per cent of the values of the ore. These properties are in the eastern or central portion of the belt. The western portion of the quartz-monzonite area is owned by the Giroux Copper Mining Company.

The quartz-monzonite mass is surrounded by contact-metamorphic limestones and shales, in which there are pockets of ore, but up to the present time no large ore bodies have been found in such rocks.

NEW MEXICO.

Copper mining in New Mexico during 1905 has not shown the same marked improvement in condition as in Arizona. The Territory contains a dozen or more areas of igneous rock surrounded by borders of limestone which has been altered by contact metamorphism and impregnated by copper ores. Various attempts have been made to work these low-grade ores, notably in the San Pedro Mountains, but thus far without marked success. There seems no question as to the abundance of low-grade garnetiferous ore at all these localities, but the future utilization of these ores is a metallurgical problem. The extension of railroad lines in 1904 has altered conditions materially, and with the assurance of cheaper coke the possibility of successful reduction seems more hopeful. The Santa Rita mines continue to produce the largest amount of ore.

The copper output of New Mexico for 1905 is estimated at 3,500,000 pounds, nearly all from Grant County. The returns for 1904[a] show the following production by counties:

Production of copper in New Mexico, 1904, by counties.

County.	Quantity.	Value.	County.	Quantity.	Value.
	Pounds.			*Pounds.*	
Donna Ana	40,000	$5,200	Santa Fe	2,308	$300
Grant	4,428,508	575,706	Sierra	16,700	2,171
Luna	16,000	2,080	Socorro	425,508	55,316
Otero	14,400	1,872	Taos	3,000	390
Rio Arriba	846	110			
San Miguel	24,900	3,237	Total	4,972,170	646,382

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[a] Lindgren, Waldemar, Production of gold and silver in 1904: Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905.

The copper ores yielded gold to the value of $85,525 and 79,369 ounces of silver.

Donna Ana County contains copper mines in the Organ district, in which the Torpedo, Memphis, Copper Bar, Excelsior, and other properties occur along a contact between altered limestone and igneous rocks, the conditions being somewhat similar to those observed at Clifton. The copper occurs in the central portion of the contact, where the limestone has been converted into garnet, vesuvianite, and epidote.

The Silver City district, Grant County, in which the Comanche Mining and Smelting Company's property is situated, furnishes the copper ores of this part of the Territory. This company owns the Hearst mine, which works a body of low-grade sulphide copper ore, developed to a depth of 800 feet. The ore is, however, refractory and contains a large amount of zinc. The company is actively developing its mines at Burro Mountain and Pinos Altos. The new concentrator has a 400-ton capacity to treat complex sulphide ores, with a 250-ton furnace, and is developing ground on the 200-foot level of the No. 8 shaft.

In the Burro district, in the same region, the 100-ton concentrating plant owned by the Burro Mountain Copper Company was in operation during the year, and has recently been remodeled.

In the Central district the Santa Rita mines continue to furnish the bulk of the copper output of the Territory. The Santa Rita property is said to show an underlying core of igneous rock, with an overlying bed of quartzite about 50 feet thick, which is impregnated with oxide ores. The quartzite lies at a gentle angle, and is overlain at some distance from the mines proper by an altered limestone, which has presumably been eroded off from the vicinity of the mines and during this erosion has furnished the solutions for the impregnation of the quartzite. Sulphide ores also occur in the underlying porphyry, extending downward as deep as the workings have been carried, about 300 feet below the surface.

In the Mogollon district bornite ores have been mined in small quantities and shipped to the custom smelters.

The "Red Beds" area of New Mexico covers a considerable portion of the Territory and contains extensive deposits of oxidized ore. The utilization of these low-grade ores has been attempted by various companies, but thus far without bringing in any large producers. The character of these deposits has been discussed elsewhere. The Blake mine of San Miguel County is the chief producer.

In the Virginia and Pyramid districts, which lie immediately south of Lordsburg, the Bonney Mining Company has developed complex copper ores carrying lead, with gold and silver values. The Robert E. Lee and Nellie Bly mines, of the Pyramid Peak district, have encountered bornite ore near the surface, with chalcopyrite ore carrying about 6 per cent of copper and 7 ounces of silver. The production from the Central district for 1905 shows a marked decrease from that for 1904.

Otero County yields a small production from the mines in the Jarilla Mountains.

Luna County contains the Apache mine, near Hachita, which is a small producer.

Sierra County contains a few small copper mines near Hillsboro.

The copper production of Socorro County comes from the mixed sulphide ores of the Magdalena Mountains.

Taos County has an insignificant production from small streaks of chalcopyrite in schist.

Sandoval County contains the Nacimiento district, where the ore occurs as fossil palm leaves and tree trunks, consisting of copper glance occurring in Triassic standstones. The deposits are not worked.

OREGON.

The northern extension of the copper belt of California passes into Josephine County, Oreg. Several properties have been developed and within the last year the Takilma Smelting Company, near Waldo, has been in operation. No returns for 1905 are yet available. In 1904 there were four producing counties in the State, but of the aggregate of 269,510 pounds all but 6,000 pounds came from the Takilma smelter. So far as information is available the ore bodies of this region consist of chalcopyrite ores, with a little bornite, in a gangue of pyrite and pyrrhotite. They form lenticular masses inclosed in altered and schistose igneous rocks, but as the locality has not been visited by any member of the Survey no detailed information is available.

In eastern Oregon there are a number of copper properties which have attracted more or less attention for some years past. They occur in the Blue Mountain region, and most of the deposits are contained in Triassic lavas, mainly basaltic, interbedded with sedimentary rocks of the same age. Three types have been distinguished by Lindgren—the Seven Devils type, the Tourmaline type, and the Snake River type.

The first named includes contact deposits of irregular bodies of chalcopyrite and bornite, lying between limestone and diorite. The ores contain a gangue of garnet, epidote, and other contact minerals. The only example of this type occurs near Medical Springs.

The Tourmaline type is characterized by chalcopyrite and pyrite associated with a gangue of quartz and tourmaline, the ores occurring in fissure veins and irregular replacements. The Copperopolis mine, in the Quartzburg district, and the Jessie vein, in the Mineral district, are of this character.

The Snake River deposits occur in the canyon of that stream, southwest of Seven Devils, 80 miles from Baker City. The type consists of deposits, largely of metasomatic origin, of finely distributed copper glance, bornite, and rarely of chalcopyrite, in Triassic lavas or tuffs. The distribution of the sulphides is irregular, but commonly follows well-defined directions, probably determined by joint systems, though no sharply defined fissures could be observed. The gangue minerals are quartz, epidote, actinolite, or chlorite. At Copper Union and near Ballards Ferry, in the Snake River Canyon, the deposits are epidotic. In the Snowstorm mine, near Sanger, the rock is a diabase and the ore actinolitic. The Iron Dike and River Queen deposits are chloritic.

The Copper Butte district contains a number of deposits in basaltic rocks of Triassic age.

Among the copper deposits noted in the foregoing paragraphs there are no producing mines, though small shipments of high-grade ores have been made from one or two of the prospects. In general it may be said that the ores are of low grade and that the zones will not average more than 1 or 2 per cent of copper.

TENNESSEE.

The copper production of Tennessee comes entirely from the Ducktown district. The output for 1905 showed only a slight increase over that of 1904, as the four new furnaces were not put in commission. The Tennessee Company produced 7,977,982 pouunds.

The production for the last six months of the year averaged about 1,000,000 pounds of copper per month, the recovery being 35 pounds of copper per ton of ore. The Burra Burra ore carries 2.3 per cent of copper, 0.33 ounce of silver, 0.001 ounce of gold, and 0.01 per cent of tellurium and selenium per ton. It is concentrated 50 to 1 by matting and converting to a pig copper carrying 99.4 per cent of copper, 12.5 ounces of silver, 0.025 ounce of gold, 0.01 per cent of tellurium and selenium, and 0.0007 per cent of arsenic.

GEOLOGY.

The Ducktown district is in the extreme southeast corner of the State, on one of the lines of the Louisville and Nashville Railroad. The deposits outcrop on a small upland plateau inclosed by higher mountains and trenched by stream channels. The country rock is a thinly foliated mica-schist with occasional intercalated layers of gneiss. The rocks are commonly regarded as part of the "Ocoee" series of Cambrian age, but they differ from the rocks of this series as exposed in the Hiwassee gorge. The foliation runs north-northeast and the beds dip 50° SE. Microscopic study by Kemp [a] shows the rocks to consist of biotite and quartz, indicating a sedimentary origin; the conclusions reached by Keith are in accord with this.

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[a] Trans. Am. Inst. Min. Eng., vol. 31, 1901, p. 244.

The ore consists of massive pyrrhotite, containing interspersed particles and stringers of chalcopyrite and pyrite, together with minute quantities of galena and zinc. Calcite, zoisite, quartz, and occasional bunches of garnet occur, with actinolite in some deposits. The copper content averages about 2.12 per cent.

The deposits consist of long and exceptionally thick masses of solid ore, rarely with few included slivers or horses of country rock. These deposits occur on three lines of fracturing and probable faulting and rock crushing. They are classed as replacement veins, similar to those at Ore Knob, N. C., and the gossan lead of southwestern Virginia, but the ore bodies are larger. Diagonal faulting of the ore bodies has occurred.[a]

DEVELOPMENT.

The London and Burra Burra mines are on the westernmost vein, the Isabella on the middle, and the Polk County, Mary, and Calloway mines on the southeast vein of the district. The Tennessee vein lies west of the last mentioned and there are two smaller intermediate ore bodies.

The deposits are extensively worked by two companies—the Ducktown Sulphur, Copper and Iron Company (commonly known as the English company) and the Tennessee Copper Company. The Burra Burra mine of the latter company is now 560 feet deep, the ore body maintaining its nearly uniform dip (of 60°) and thickness to the lowest workings.

The Tennessee Company is preparing to erect an acid plant to make low-grade sulphuric acid out of the fumes from the blast furnaces.

The ore of the different mines has the following composition:[b]

Composition of Ducktown ores.

	1.	2.	3.	4.
Copper	2.744	2.79	2.2	3.0
Iron	36.519	43.26	37.5	31.0
Sulphur	24.848	29.18	30.0	21.0
Silica	18.548	10.01	10.3	26.3
Lime	7.294	6.32	6.2	6.1
Magnesia	2.672	1.39	1.9	2.5
Zinc	2.556	2.56	2.0	.8
Alumina	.911	1.00	3.9	4.4
Manganese	.770	.69	....	....
Carbon dioxid (by difference)	3.135	2.80	....	....
	100.000	100.00	....	....

The first two columns represent the ores smelted by the Ducktown Copper, Sulphur and Iron Company; the third and fourth columns the ores of the Burra Burra and London mines, respectively, both being from the same vein. It will be seen that there is considerable difference in the composition of the ores from the different parts of the same ore body.

The Ducktown ores are no longer roasted, but are smelted raw, in blast furnaces, with a concentration of about 7.3 into 1, forming a 12 to 20 per cent matte, which is resmelted with a small amount of raw ore, quartz, etc., and raised to a 50 per cent matte, which is in turn bessemerized.

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[a] Henrich, Carl, Trans. Am. Inst. Min. Eng., vol. 25, 1895, p. 198.

[b] Channing, J. Parke, Pyrite Smelting, p. 254. Freeland, W. H., Raw sulphide smelting at Ducktown: Pyrite Smelting, p. 111.

UTAH.

The copper production of Utah for 1905 has been estimated at 57,267,000 pounds,[a] valued at $8,785,000. This output comes mainly from the copper mines of Bingham and Park City, the increase of over 13,000,000 pounds of copper over the production for 1904 being due to these two camps. The Utah Consolidated, of Bingham, has paid out over $1,000,000 in dividends during the past year, and the United States, another copper producer, $750,000 in dividends.

The Bingham camp has been successfully developed until it is now one of the greatest copper camps of the country. In addition to the production from the well-known flat ore bodies in the limestone, the copper-bearing monzonite ores have been proved to be of great economic value. The Utah Copper Company and the Boston Consolidated both work the so-called porphyry or disseminated ores, and as the ore bodies can be mined in places by steam shovels and a 3,000-ton mill is nearly completed by the Boston Company, a greatly increased output from this source may be expected in 1906. The Utah Copper Company has a plant of the same capacity now in process of erection, and it is said that these two companies have over 60,000,000 tons of ore available for extraction. A third group of mines on this porphyry belt is that known as the Starless group. All the companies operating in this vicinity have enlarged their plants, and the output will be greatly increased in 1906.

Park City, which produces copper as a by-product, has not been as prosperous as Bingham, though its output has been maintained at about the same point as in the previous year. The chief development has been in the Bonanza Flat section, where the West Quincy and Little Bell companies have carried on extensive development.

The Tintic district has shipped about 300,000 tons of ore from the 12 chief mines in operation, although there are 35 shipping properties. The Centennial-Eureka has, as usual, been the chief producer.

At Alta extensive development work has been done and new ore bodies opened up, and this once famous silver camp promises to become second to Bingham as a copper producer if present indications do not prove delusive.

The Cactus mine, in Beaver County, has been operated since March, 1905, producing about 10,000 tons of concentrates in 1905. The company expects to install steam shovels in 1906, which will greatly reduce the cost of mining.

The Utah and Eastern Copper Company has blown in its smelter, in Washington County, after some six months of idleness, and as the ore body has been cut by a deep drain tunnel, the outlook is hopeful for a continued production. A small smelter is also operated by the Paymaster Copper Company.

The production of the State for 1903 and 1904, by counties, is as follows:

Production of copper in Utah, 1903 and 1904, by counties.

County.	1903.	1904.
	Pounds.	*Pounds.*
Beaver and Piute	432,409	1,650,787
Juab and Utah	8,023,464	9,035,720
Salt Lake	18,604,989	30,864,666
Summit and Wasatch	3,297,101	2,118,452
Tooele	984,295	1,023,825
Washington, Millard, Sevier, Grand, and Boxelder	1,505,398	1,723,784
	32,847,656	46,417,234

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[a] Beason, H. L., Eng. and Min. Jour., Jan. 6, 1906.

Bingham is the most important copper district of Utah. A monograph describing the district, by J. M. Boutwell, has recently been published by this Survey. The conclusions reached by Boutwell[a] as to the genesis of the Bingham deposits are as follows:

In Mesozoic or early Tertiary time intrusive bodies of monzonite invaded a mass of quartzites and limestones, producing contact metamorphism, with the intrusion of pyritous copper sulphides as replacement of marmorized limestone. After the cooling of the upper part of the intrusive monzonite to at least partial rigidity it and the inclosing sedimentary rocks were fractured by persistent northwest-southeast fissures. Heated aqueous solutions from the deeper unconsolidated portions of the magma ascended through these fissures, altering the fissure walls and introduced additional metallic material, adding to the deposits in the limestones, altering the monzonite and adding copper, gold, and silver as auriferous chalcopyrite, pyrite, and molybdenite to the monzonite. Two periods of mineralization are clearly defined—first, that of contact metamorphism, with intergrowth of ore, garnet, etc.; second, after actions, producing the disseminated ores and the lodes.

The site of the ore bodies was determined by selective preference of mineral solutions for deposition in certain beds, a preference quite as marked with different limestone beds as it is between limestone and quartzite.[b] The disseminated ores[c] were deposited by hydrothermal action subsequent to the date of the igneous intrusion, and the sulphides are now undergoing normal superficial alteration. The ores occur in the joints of the rock as a mossy coating of quartz and sulphides, but also in the body of the rock, especially associated with dark ores of ferromagnesian minerals, principally secondary (?) biotite. The productive ground was coextensive with monzonite exposures, as may be seen by comparison of the geologic and economic maps. All the monzonite was, however, not mineralized, and it was only where extensive fracturing permitted the access of the deep-seated solution that mineralization was extensive enough to form workable ore deposits. In the Utah Company's claims an average assay of 6,000 samples corresponds closely to the grade of ore now milled, showing 1.98 per cent of copper, 0.016 ounce of gold, and 0.15 ounce of silver per ton.

The Newhouse or Cactus mine, in Beaver County, is now one of the regular producers of the State. A description of this property, by S. F. Emmons, is given in Bulletin No. 260, page 242. The mine is 4½ miles northwest of Frisco, in the San Francisco Mountains, and is reached by a branch line of the San Pedro, Los Angeles and Salt Lake Railroad. The ore consists of coarsely crystalline pyrite, with a little chalcopyrite and rarely sooty sulphide. The deposit is a shear or crush zone in monzonite, 15 to 30 feet wide, the ore cementing fragments and filling cracks and crevices in the shattered rock. The ore zone is vertical and is developed to a depth of 600 feet by a shaft and a crosscut tunnel over a mile long. While the mine yields some smelting ore, the main product is concentrating ore treated in an 800-ton mill and concentrated 6 into 1. The shear zone is a strong fault zone, traceable for a mile or more across the mountain slopes running toward the Horn Silver fault.

The Park City district, though better known as a producer of argentiferous lead ores, yields an important and rapidly increasing output of copper ore. Copper is commonly present as tetrahedrite (gray copper), or fahlore, in the high-grade silver ores, the average of such ores carrying about 2.5 per cent of copper, 40 per cent of lead, and 60 ounces of silver per ton, while the crude ore sent to the concentrators carries 1.5 per cent of copper.

The ore occurs in fissure lodes and as masses in limestone, the bulk of the ore now extracted coming from the bedded ore bodies in limestone. The northeast-southwest fissures, with steep northwesterly dip, are wide and persistent veins, 2 to 35 feet wide, carrying narrow pay streaks of high-grade ore.

The "bedded" deposits are replacements of and occur in certain layers in Upper Carboniferous and Permian limestones, the ore-bearing layers being inclosed in quartzite. Both lodes and replacement bodies occur intimately associated with porphyry intrusions.

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[a] Prof. Paper U. S. Geol. Survey No. 38, 1905, p. 229. [b] P. 128. See fig. 2. [c] P. 172.

Development of these ore bodies has been very extensive. It is possible to walk for nearly 5 miles in one general direction underground, and the Ontario shaft is 2,000 feet deep. The Ontario, Daly West, Daly Judge, and Silver King are the largest companies.

Tintic produced 2,118,432 pounds of copper ore in 1904, carrying 59,213 ounces of gold and 1,655,139 ounces of silver, contained in 262,680 tons of ore and concentrates. The copper was about equal in value to the gold content of the ore, the combined value of gold and copper being $546,805, as against 6,126,332 ounces of silver and lead.

Bingham produced 705,792 tons of ore in 1904, of which 137,979 tons were milling ore, yielding 9,515 tons concentrates, valued at $510,291. The district yields practically no siliceous ore, and the copper produced carried 54,609 ounces of gold and 906,768 ounces of silver.

Mercur, Tooele County, yielded 1,023,825 pounds of copper in 1904, of a value of $127,978.

WASHINGTON.

The copper product of Washington comes chiefly from the mines situated in the eastern part of the State, though numerous prospects exist in the Lake Chelan region and in the Cascade Mountains near Index station, on the Great Northern Railway.

The production for 1904, by counties, is as follows:

Production of copper in Washington, 1904, by counties.

County.	Pounds.	Value.
Ferry	77,548	$8,948
Kittitas	329	46
Snohomish	77,850	8,991
Stevens	194,320	25,803
	350,047	43,788

The Copper King mine, a property situated 4 to 5 miles from Chewelah, Stevens County, is shipping ore to the Northport smelter. The ore consists of chalcopyrite and is said in occur in a schistose rock with granite near by. The ore is hauled to the railroad by a traction engine, which draws six cars of 10 tons each and makes three trips every two days.

At Chesaw, Ferry County, near the boundary line, northwest of Republic, the First Thought, Orient, and Belcher mines have been developed to a point where they are capable of making a steady output.

The Belcher mine was actively developed in 1905. The ore is a fine-grained, dense, banded mixture of pyrite and chalcopyrite. The district is underlain by diorite[a] and syenite-porphyry. The ore bodies occur in east-west fractures in the diorite with northerly dip. The ore occurs both in nearly pure bodies and with country rock. The largest shoot in Belcher No. 2 is of massive pyrite ore; it has an extreme width of 80 feet and is 100 feet long. Pyrrhotite is abundant in some veins and carries low gold values. The Belcher has five tunnels and several open cuts.

The ores at Index, Snohomish County, consist of granite impregnated with bornite and are quite siliceous, so that they can be treated only by mixing with the basic ores of other localities, the mixture of ore and gangue being too intimate to permit of cheap concentration by water.

WYOMING.

The principal copper-producing section of Wyoming is the Encampment district, which lies in the southern part of the State and extends from the Colorado boundary northward, on both sides of Platte River. Most of it is in southern Carbon County, and the remainder is in southern Albany County. A part of the same geographical section is the Pearl district of northern Colorado. Encampment, Carbon County, has the only large smelter in Wyoming, and an aerial tramway, 16 miles in length, the longest in the West, connects the smelter with the Ferris-Haggarty mine. The smelter, tramway, mine, and other property of the North American Copper Company were, after default in the payment of interest on bonds and a foreclosure, taken over by its successor, the Penn-Wyoming Copper Company.

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[a] Mining World, Jan. 9, 1904, p. 86.

The district has been fully described by Spencer,[a] from whose paper the following synopsis has been taken:

The region is one of quartzites and schists. The beds have a prevailing east-west course and dip steeply to the north and are intruded by igneous rocks. The ore bodies are reconcentration enrichments along channels, due to the netted fracturing of the rocks.

The ore is siliceous and needs an iron flux, gossan for this purpose being mined at a locality 9 miles away and hauled to the smelter.

The smelter is at the town of Encampment. The ore is carried by rope tramway 16 miles across the range, over two divides and two valleys. Coal is supplied from a locality 8 miles from the mines and hauled up grade in wagons to the furnaces. There are two producing mines—the Ferris-Haggarty and the Doane.

The Doane-Rambler mine is the second largest of the Encampment district. The shaft is now (1905) 600 feet deep, with several hundred feet of drifts cutting through both low-grade and high-grade ores. The property is equipped with a complete machinery plant and is said to have the largest ore reserves of any mine in the district.

The Ferris-Haggarty ore body lies between steeply dipping schists and quartzites, the schists lying above the ore. The ore consists of chalcocite and chalcopyrite impregnating and replacing crushed quartzite, which forms the gangue. Much of the ore requires concentration. The ore body is 250 to 300 feet long, and varies from a few inches in thickness at the end up to 30 feet in the middle. The schist hanging wall is very regular; the foot wall is very irregular, being governed by the amount of brecciation or fracturing of the quartzite. But one pipe of ore has as yet been found.

The Doane is of the same type. The ore is glance, with lesser amounts of chalcopyrite, bornite, and rarely of covellite. The ore body is an elliptical "pipe" lying in a bed of quartzite, dipping steeply to the north, the ore shoot having a wavy pitch to the west.

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[a] Prof. Paper U. S. Geol. Survey No. 25, 1904.

THE CASHIN MINE, MONTROSE COUNTY, COLO.

By W. H. Emmons.

INTRODUCTION.

The Cashin copper mine is situated at Cashin post-office, in the western part of Montrose County, southwestern Colorado, on La Sal Creek, about 4 miles west of its junction with Dolores River. In June, 1905, it was the writer's privilege to make a hasty visit to this property incidental to a geological reconnaissance under the direction of Mr. Whitman Cross. The nearest railroad station, Placerville, on the Rio Grande Southern, is about 70 miles to the east. The wagon road between the two points is said to be in very good condition and of moderate grade for a rugged topography.

The region is a portion of the plateau country which under various names constitutes a large part of southwestern Colorado and southeastern Utah and extends southward into New Mexico and Arizona. The country is traversed by deep and relatively narrow canyons, the steep, inaccessible walls of sedimentary rock presenting a picture similar to that of the Grand Canyon of the Colorado in Arizona, although the relief is much less. The climate is arid, but the La Sal Mountains, about 10 or 12 miles to the west, furnish an abundant supply of water and power.

The deposit was discovered in 1896, but active development did not begin until 1899. Since then it has been worked with varying success most of the time. According to the books of the La Sal Copper Mining Company, the present owners, it has produced altogether 363,778 ounces of silver and 732,740 pounds of copper.[a]

GEOLOGY.

The country is underlain by nearly horizontal sedimentary rocks, strongly fissured and faulted.

The generalized geologic section, as observed in Paradox and Sinbads valleys several miles north of Cashin, is as follows: [b]

Generalized section north of Cashin, Colo.

	Thickness in feet.
1. Dakota formation (Cretaceous): Sandstone, white or buff, often bearing abundant plant remains and thin coal seams	200–400
2. McElmo formation (Jurassic): Sandstone with shaly members, often massive; light pink or white	400
3. La Plata formation (Jurassic): Massive sandstones, with occasional thin-bedded or shaly layers; pink or nearly white	600–800
4. Dolores formation (Triassic): Fine-grained red sandstones, often thin bedded, alternating with sandy or calcareous red clay shales. Contains one or more beds of limestone conglomerate, usually bearing the remains of plants and small pieces of bone ("Saurian conglomerate"). Probably rests on Permian conglomerates	200–400

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[a] These figures do not include the shipments of native copper, of which no record was available.

[b] The writer was unable to visit the country between the mine and Dolores River, where that portion of the section which comes below the present workings would probably be exposed. The thickness of the La Plata is exposed in the cliff above the mine, and the persistence of the limestone-conglomerate beds ("Saurian conglomerate") indicates that this limestone layer should appear not far from the present lower workings. It could probably be traced from its exposure south of the Paradox bridge up La Sal Creek and its position below Cashin determined with some degree of certainty. It would be interesting to know what change, if any, occurs in the ore body where the fissure crosses this limestone member.

In Sinbads Valley massive Carboniferous limestones, belonging below the Permian conglomerates, are exposed. It is probable, therefore, that considerable thicknesses of both of these strata would be crossed before the basal granite was reached.

The Dolores formation in its typical development of red sandy shales and limestone conglomerates was observed just south of the bridge crossing Dolores River at Paradox. It is the base of the section as there exposed. In the country to the north and west the Cutler formation (Permian) underlies the Dolores and consists of a great thickness of red sandstones and conglomerates, with occasional beds of red shale and lenses of gypsum. At several places the Cutler and Dolores are separated by an angular unconformity, showing that there was tilting and erosion between the periods of their deposition, but in Paradox Valley their dip appears to be uniform.

The La Plata formation occupies a large area in this region and often forms the "rim rock" of the valleys. The later formations generally occur as more or less isolated areas on the higher portions of the plateau. In Paradox and Sinbads valleys the rocks are complexly dislocated by faults of considerable throw—in some cases several hundred feet. A pronounced fissure trends northward from Cashin to Paradox Valley. The crushed sandstone along this fissure shows that it has been a plane of movement, though the beds show little displacement.

There are no igneous rocks in the immediate vicinity of the mine. A body of "porphyry" is reported to occur 6 miles southwest of Cashin, and the La Sal Mountains, a laccolithic group, are about 10 or 12 miles to the west.

To judge from the thickness of the La Plata sandstone above the mine, the tunnel must enter that formation near its base and the Triassic limestone conglomerate, if present, would appear near the lower workings. Mr. J. N. McBride states that the ore becomes very much richer in lime in that portion of the mine, and this may be because of the proximity of the limestone. There is so much crushed quartz, kaolin, and secondary calcite at this point that with the present limited development here, the country rock could not be determined with certainty.

ORE DEPOSITS.

The ore deposits occur along a fissure which cuts the La Plata sandstone. The dip of this fissure is 75° W. and, though it bends slightly, its general strike is about N. 20° E. According to Mr. Thomas L. Darby, the fissure may be traced on the surface northward to the rim of Paradox Valley, 2 or 3 miles distant, but the writer was unable to examine this portion of the lode, nor to observe its behavior in the formations above the La Plata. A tunnel with its portal about 30 feet above La Sal Creek has been driven northward on the lode for 700 feet. An inclined shaft connecting with the surface and extending 100 feet below the level of the tunnel crosses it about halfway to the breast, thus exposing 400 feet of beds. In places considerable ground above the tunnel has been stoped out and short drifts have been run on the vein at several levels.

The nonmetallic minerals are crushed quartz sand, kaolin, calcite, barite, and vein quartz. The metallic minerals are covellite, chalcocite, bornite, native copper, malachite, azurite, cuprite, and iron sulphate. Argentite and native silver occur near the surface in pockets of considerable size, but at the time of visit these had been removed.

The lode varies in width from 1 foot to 20 feet or more and is composed mainly of crushed sand and kaolin, containing small specks of copper sulphides. It is often stained green by copper carbonate and iron sulphate. There is not always a distinct line of demarcation between the lode and the wall rock, since the lode is made up largely of the material of the country rock, altered somewhat by movement and concomitant processes. The green discoloration sometimes extends beyond the fissure, a feature which is strikingly shown on the face of the cliff southwest of the portal of the tunnel.

Rich ore, composed largely of argentiferous covellite, chalcocite, and bornite and also carrying calcite and barite, occurs as veinlets in the fissure zone. These veinlets are from 1 inch to several inches wide and are sometimes composed entirely of the copper sulphides, the brilliant blue of the covellite contrasting strongly with the dark chalcocite and making an ore of unusual beauty. The veinlets are generally approximately parallel to the direction of the fissure, but sometimes cut diagonally across it. Where the lode is widest, there are four or five of these veinlets. Frequently they play out along a narrow seam, perhaps to reappear beyond. Carload shipments of the rich ore have given returns as high as 512 ounces of silver to the ton. Large masses of the native copper occur embedded in the kaolin, especially in the lowest level. Most of them are irregular bodies about as thick as they are long, and one was found which weighed over 500 pounds. A sheet of leaf copper was observed on the dump. It was about a foot square and one-eighth of an inch thick, and was slickensided on both sides. Native copper also occurs in veinlets with calcite and barite, and one shipment averaged 89 per cent copper and 77 ounces of silver to the ton.

TREATMENT OF THE ORE.

On account of the excessive hauling charges, only the high-grade ore can be profitably shipped. Of this ore the mine has produced 2,067 tons, which averaged 12.5 per cent copper and 134 ounces of silver to the ton.

The Russel leaching process, by which the roasted and crushed ore was treated with a weak solution of hyposulphite of soda, proved successful so far as the silver was concerned, recovering 89 per cent of the values, but it was too expensive for the recovery of the copper. By this method 3,100 tons were treated at the mine, yielding an average of 3.5 per cent copper and 28 ounces of silver to the ton. A small smelter was also installed. Iron pyrite was shipped from Ophir, Colo., and coke from Dakota coal was obtained from ovens about 4 miles west of Naturita, or 28 miles east of the mine. The product was a copper matte running high in silver.

PROBABLE ORIGIN OF THE ORE.

S. F. Emmons,[a] in reviewing the occurrence of copper in the "Red Beds" of the Colorado Plateau, mentions a large number of deposits which are found in sedimentary rocks far from outcrops of contemporaneous or later igneous rocks. In regard to the origin of some of these occurences, his observations "favor the idea that the ore has been leached down from above and is of secondary origin, rather than that it is an original deposit from uprising solutions." F. L. Ransome,[b] in discussing the uranium and vanadium minerals, which occur in the La Plata sandstone of the Colorado Plateau near Placerville, Colo., and elsewhere, suggests that the deposits of these minerals "are local concentrations from the bulk of the sandstone." The ore deposits at Cashin probably belong generically to the same class, though they are distinctly fissure deposits. It is always possible that an igneous body may underlie any sedimentary rock, and the laccolith which formed the La Sal Mountains may have sent out thin intrusive sheets between the sediments to points much nearer Cashin than those at which these rocks now outcrop; but such intrusive sheets were not observed at any of the places where they should be revealed at points nearer the La Sal Mountains than the Cashin mine and at horizons lower in the sedimentary series.

The general occurrence of small bodies of low-grade copper minerals in the "Red Beds" of the Colorado Plateau suggests these formations as a possible source of the Cashin ores. The sedimentary rocks, consisting mainly of massive sandstones alternating with thin-bedded sandstones and shales, dip toward Cashin from the La Sal Mountains. Their higher outcrop is several thousand feet above their outcrop at Cashin, and the dip of the beds is approximately the slope of the surface. The water circulation is down the dip from the higher country, and where the rocks are cut through by erosion it manifests itself as springs in the deeper valleys. Often these springs are highly charged with salt or alkali, and some of them contain considerable quantities of hydrogen sulphide. Such springs were noted in Fisher Creek Canyon north of the La Sal Mountains. It is not known whether or not these waters carry a trace of copper, but some of them are at least capable of dissolving copper, and others would precipitate the metal from dilute solutions. The solutions, moving down the dip in the various sandy beds, would rise when they reached the fissure and an artesian circulation would be established. In the fissure the mingling of solutions would cause a precipitation of metallic sulphides. The absorptive action of the kaolin, which is abundant in the zone of crushed quartz, may also have operated to deposit the ore.

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[a] Bull. U. S. Geol. Survey No. 260, 1905, p. 221.

[b] Am. Jour. Sci., August, 1900, p. 120.

The veinlets of argentiferous copper sulphides suggest that there has been a secondary concentration of the ore. All the metallic minerals belong either to the group which is commonly regarded as secondary or are those which usually occur in the oxidized zone. So far as the development has proceeded, there is nothing to indicate that the original ore was a copper-iron sulphide, for pyrite and chalcopyrite are almost entirely absent, and a complete analysis of the dump gave less than 2 per cent of iron.

ORE DEPOSITS IN THE ST. JOE RIVER BASIN, IDAHO.[a]

By Arthur J. Collier.

INTRODUCTION.

The region herein described lies south of and adjacent to the Cœur d'Alene mining districts of northern Idaho, which are the most important sources of argentiferous lead ore in the United States. It comprises parts of 30 townships, mostly unsurveyed, included within the limits of the Northern Pacific land grant. Though not very remote from railroads and populous mining towns, it is undeveloped and practically unexplored, since it is situated in the heart of the Cœur d'Alene Mountains. For this reason it has been included within the limits of the proposed Shoshone Forest Reservation. In 1899, 1900, and 1901 these lands were investigated by a United States mineral commission, appointed to examine lands within the Northern Pacific grant, and were by that commission classified as mineral lands.[b]

This classification being protested by the Northern Pacific Railway, F. M. Goodwin, special agent of the General Land Office, and the writer were detailed to make an examination of the lands in question preparatory to a hearing ordered for October 1, 1905, at the land office in Cœur d'Alene, Idaho. In accordance with instructions two months were spent in a rapid reconnaissance of the region in controversy, in the course of which a sketch map of the parts traversed was made and nearly all the reported prospects of valuable minerals were examined. Surface indications of silver, lead, copper, and gold ores were found to be widely distributed in the region, but there has been little development and, with one exception, no commercial ores have been produced. The following notes and maps, based on the writer's own investigations and the sworn testimony of many other witnesses, have been prepared in view of the fact that the region is practically unknown, either geologically or geographically, and because the surface indications of valuable ores seem to warrant investigation.

GEOGRAPHY.

Nearly all these lands (see Pl. IV) lie within the drainage basin of St. Joe River, a tributary of Lake Cœur d'Alene. A small part along the southern border is drained by Little North Fork of the Clearwater. The western limit of the area is near meridian 116° 10′, and it extends eastward to the Montana-Idaho boundary, which in a sinuous line follows the summit of the Cœur d'Alene Range. This district (see sketch map, fig. 6) lies south of and adjacent to the area which was covered by the Cœur d'Alene special map of the United States Geological Survey and whose geologic and economic features have been described by Ransome.[a] Its southern boundary is about 20 miles north of the northern limit of the area covered in Lindgren's reconnaissance across the Bitterroot Range.[b]

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[a] This river has appeared on nearly all published maps as the St. Joseph. The name as written above, however, conforms with local usage and has recently been approved by the Board on Geographic Names.

[b] The act creating this commission provides in part "That all said lands shall be classified as mineral which by reason of valuable mineral deposits are open to exploration, occupation, and purchase under the provisions of the United States mining laws, and the commissioners in making the classification herein provided for shall take into consideration the mineral discovered or developed on or adjacent to such lands, and the geological formation of all lands to be examined and classified, or the lands adjacent thereto, and the reasonable probabilities of such land containing valuable mineral deposits because of its said formation, location, or character." (Sec. 3, act of February 26, 1895, 28 Stat. L., 683.)

This region is traversed by few lines of travel. Steamboats on St. Joe River can approach within 15 miles, and above the head of such navigation canoes can be poled up the swift water well into the heart of the district here described. There are, consequently, a few scattered settlements along the river. Along the main divides old, well-beaten trails, often referred to as parts of the "Lolo" trail, have been traveled by the Indians since prehistoric times. There are also two trails made by hunters and trappers, which start from Wallace and De Borgia, respectively, and cross the St. Joe drainage basin from north to south, joining the "Lolo" trail on the Clearwater divide. The northeastern border of the district is crossed for half a mile by a wagon road built from Saltese, Mont., a station on the Northern Pacific Railway, but with this exception there are no wagon roads, though a contract has been let for building one along the Wallace trail to the St. Joe.

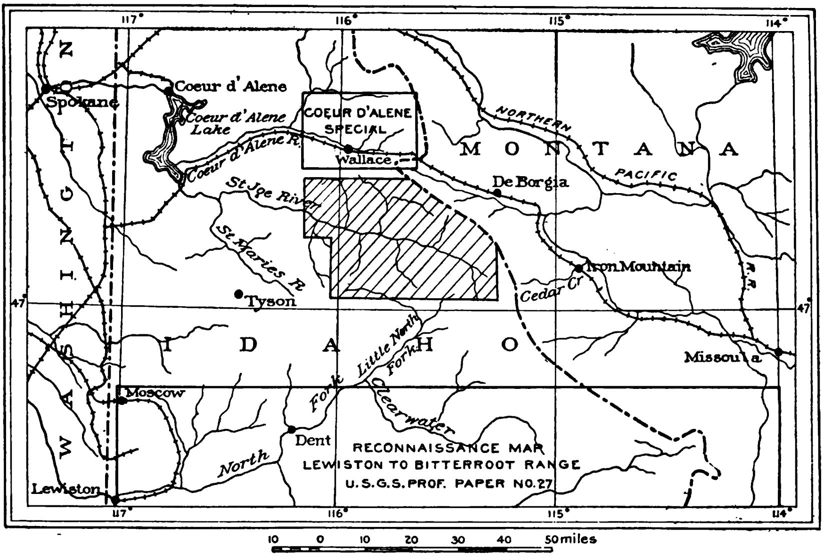

FIG. 6.—Map showing location of St. Joe River basin.

TIMBER AND AGRICULTURAL LANDS.

The whole region has been more or less heavily timbered, but forest fires occurring at intervals during the last twenty years have burned over large areas. About 15 per cent of the land, distributed in small patches, carries merchantable timber. Nearly all of the remainder is covered by a thick growth of underbrush and small trees, some of which are large enough for mining purposes. For this reason prospecting and travel away from the trails are difficult. All the mountains and ridges which rise above an elevation of 5,000 feet are timbered with "balsam fir" and hemlock, reported to be of little value, but at lower elevations the timber consists of red fir, white pine, tamarack, and cedar, all of which are valuable.

The agricultural lands are confined to the narrow bottoms along the creeks and rivers. It has been estimated that there may be as much as 400 acres of land suitable for agriculture along St. Joe River within the district and 200 to 400 acres more distributed along some of the tributary streams. On account of the heavy undergrowth and timber only a small part of this land is suitable for grazing at the present time.

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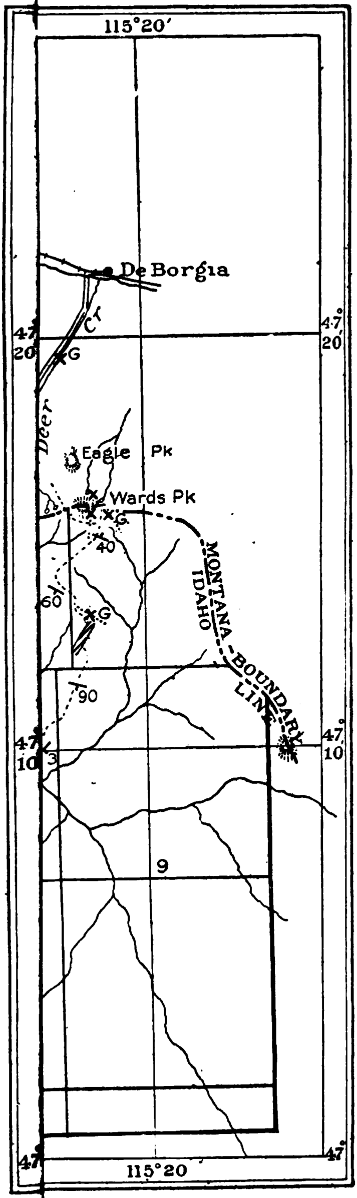
[a] Ransome, F. L., Ore deposits of the Cœur d'Alene district, Idaho: Bull. U. S. Geol. Survey No. 260, 1904, pp. 274-303.

[b] Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, Pl. I.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RELIEF AND DRAINAGE.

The relief and general topographic features are similar to those of the Cœur d'Alene mining district. The elevations range from about 7,000 feet at Wards Peak to about 2,100 feet at the lowest point within the district, on St. Joe River. Seen from the mountain tops the region has the aspect of a rolling plateau dissected by canyons to a depth of 1,000 to 3,000 feet. This plateau is regarded as a peneplain produced by the erosive action of streams and rivers when the land surface stood at a lower elevation. At that time the principle drainage channel was in a broad valley having about the same general position as St. Joe River. After the formation of this old surface the whole region for many miles both north and south of this district was elevated as a great block, from which the Cœur d'Alene Mountains have been carved.

The floor of the old valley, which in places was deeply gravel covered, has been elevated to an average height of 1,000 feet above the present river bed and dissected with the remainder of the plateau, leaving a series of gravel-capped hills. All the rivers and creeks lie in narrow canyons. They are characterized by steep gradients and comparatively large volumes of water. St. Joe River, the large trunk stream of the district, has a broad bowlder-strewn bed through most of its length, with occasional narrow flood plains and gravel benches. At two points the walls of the valley contract, forming what are locally called "box" canyons. The upper of these canyons, which lies just west of the crossing of the De Borgia trail, contains several waterfalls and marks the head of canoe navigation. Many of the tributary streams head in small glacial lakes on the flanks of the higher mountains at elevations above 5,000 feet. Their canyons contain few deposits of gravel or sand and in them the bed rocks are usually exposed. Owing to their high gradients and volumes many of the streams could be used for water power, and a few water-right locations have been made, though in no case has a power plant been installed.

GEOLOGY.

The prevailing rocks of this district comprise a series of arenaceous and argillaceous sediments, which as a whole show little contrast. Nearly all the beds are characterized by shallow-water features. The rocks are identical with those making up the series exposed in the Cœur d'Alene district, which have been examined with great care by Ransome and Calkins.[a] They are of Algonkian age and, as exposed in the area of the Cœur d'Alene special map, have a thickness of about 15,000 feet. The series comprises six formations, differing slightly from each other, which, arranged in order from the top of the series down, are called the Striped Peak, Wallace, and St. Regis formations, Revett quartzite, Burke formation, and Prichard slate. Although in the St. Joe region the rocks have been examined only in hasty reconnaissances, it seems probable from the observations made that all the formations distinguished by Ransome and Calkins in the Cœur d'Alene district are represented. The structures also are nearly if not fully as complex. The rocks are intensely folded, the dips varying from nothing to 90° and the prevailing strikes being about west-northwest. Overturned folds have been noted in a few instances and faulting is a common feature. Most of the faults strike approximately west-northwest and east-southeast, parallel with the prevailing strikes of the bed rock, though some having an approximate north-south direction have also been recognized, and in a number of instances a well-developed joint system also striking northwest and southeast was observed. In the northern part of the district the rocks are unaltered, and only the softer beds are affected by slaty cleavage. In the southern part, however, from St. Joe River to the southern limit of the region examined, the rocks become progressively more schistose, the softer beds especially being altered to mica-schists, often studded with garnet and staurolite. All gradations between the unaltered sediments of the northern part of the district and these schists can be observed.

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[a] Ransome, F. L., Ore deposits of the Cœur d'Alene district, Idaho: Bull. U. S. Geol. Survey No. 260, 1905, pp. 277-285.

Lindgren[a] has mapped a great batholith of granite, covering an area as great as 5,000 square miles, which forms the whole mass of the Bitterroot Range south of this district. The increasing schistosity of these rocks to the south is probably to be accounted for by the proximity of this great intrusive mass, the northern limits of which have not been determined.

Igneous rocks occur as dikes, sills, and stocks intruded in these sediments at various places. They fall into the two groups, diabases and granites, which are of about equal importance as regards distribution. Diabases occur as dikes and sills cutting the sedimentary rocks, more commonly in the northeastern part of the district, though some smaller dikes occur in the southern and western parts. Some of the larger areas of diabase are shown on the map, Pl. IV. The largest mass observed is cut by St. Joe River at the upper box canyon. Several smaller masses, which were observed near the Cœur d'Alene divide, between Stevens Peak and Wards Peak, appear sometimes as dikes, but more often as sills. As far as observed their outcrops either extend north and south or northwest and southeast. This rock has a granitic texture; it consists essentially of plagioclase and augite, with quartz as an accessory mineral and magnetite and ilmenite as important constituents.

The granites are more local in their distribution and have been observed by the writer only along St. Joe River in T. 45 N., Rs. 2 and 3 E. Mr. Thomas Cooney, a mining engineer employed by the Northern Pacific Railway, reports that they also occur in the E. ½ of T. 43 N., R. 5 E. Although examined only cursorily these rocks seem to be intrusive masses in quartzites of the Cœur d'Alene series, which near the contacts are changed to hornfels. They consist essentially of quartz, orthoclase and plagioclase feldspars, and biotite. All of the minerals show more or less crushing and distortion, indicating disturbances subsequent to the intrusion of the granite.

In the Cœur d'Alene district two types of igneous rock have been recognized.[b] The most important of these is a coarse-grained syenite, which has a tendency toward porphyritic development of the dominant feldspar. These rocks occur as irregular stocks and dikes and find their greatest development in the vicinity of the most productive group of lead and silver mines, though no causal relation between them and the ore deposits has been established. The rocks of the second type occur in dark-colored dikes near the southern edge of the Cœur d'Alene area, and are of minor importance in that district. They are diabases consisting essentially of plagioclase feldspar and augite, with quartz as an important accessory. The granites of the great batholith of the Bitterroot Range are described by Lindgren[c] as quartz-monzonite, a variety of granite containing both orthoclase and plagioclase feldspars.

By a comparison of the igneous rocks found in this region with those described from the Cœur d'Alene district on the north and the Bitterroot Range on the south, it seems evident that the granites of the St. Joe Valley differ considerably from the syenites of the Cœur d'Alene district and are more nearly like the quartz-monzonites of the Bitterroot batholith. The diabases are probably of almost identical character with those from the Cœur d'Alene district, but they occur in much larger masses and are therefore of more importance.

ECONOMIC GEOLOGY.

Lead-silver, copper, and gold ores have been found, and some attempts to develop valuable deposits of these minerals have been made at many places within the area under investigation, but most of the prospecting and development have been unsystematic and desultory. The region is difficult of access and devoid of means of transportation. Most of the reported mineral discoveries and prospects are situated along the northern and eastern boundaries, which are fairly accessible from the line of the Northern Pacific Railway, near the few trails which cross the district from north to south, or adjacent to canoe navigation on St. Joe River. From the evidence adduced it appears that placer gold was discovered on the headwaters of St. Joe River at what is called the St. Joe Basin as early as 1870 by prospectors crossing the divide from Iron Mountain, Montana. This district, however, is so remote from transportation and the placers are of such low grade that the ground has not yet been systematically worked, though small amounts of gold have been obtained. The search for lead-silver and copper ores was inaugurated in 1884 or 1885, after the discovery of the valuable lead-silver deposits of the Cœur d'Alenes.

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[a] Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, p. 18.

[b] Ransome, F. L., op. cit., p. 282.

[c] Lingren, Waldemar, op. cit., p. 18.

LEAD-SILVER DEPOSITS.

Croppings of rock containing galena were examined in prospect holes at several points along Slate Creek, near the trail from Wallace to St. Joe River, in T. 46 N., Rs. 4 and 5 E.; also east of North Fork of St. Joe River in T. 45 N., R. 6 E. Similar mineral indications on which considerable time and money have been spent occur in the northern part of T. 46 N., Rs. 1 and 2 E., just outside the area under investigation. The occurrence of galena-bearing rock at a number of other localities not personally examined was indicated by the testimony of various witnesses adduced at the hearing. Most of the prospects examined lie within a belt a few miles wide extending from T. 45 N., R. 6 E., in a west-northwest direction to and beyond the limits of the district under investigation. In some instances the galena-bearing rock consists of so-called "iron cap" or gossam, a mixture of hematite, limonite, and quartz containing some unaltered galena which can easily be recognized when the specimens are newly broken. In many of the prospect holes, however, the galena is found to be disseminated in small grains and veinlets through the country rock, which on the surface is yellowish brown from iron stains. In such cases the galena is associated with more or less siderite and sphalerite, together with some pyrite and chalcopyrite. This association of minerals resembles that in the ores from some of the mines of the Cœur d'Alene district,[a] which have replaced the country rock in proximity to mineralized fissures or fractures.

In sec. 14, T. 46 N., R. 5 E., gossan, consisting largely of limonite, in which there is some unaltered galena, is exposed in several prospect holes which have been abandoned and are so much caved in that the nature of the occurrence can not be determined. In sec. 13, one-fourth mile southeast of this locality, the bed rock exposed in a steep hillside shows considerable disturbance and an overturned close fold, but no definite fissures or fractures were observed. Nearly all the rocks here are iron stained and in some places contain galena disseminated in small masses. A tunnel about 40 feet long was driven several years ago, when, it is reported, considerable galena ore could have been obtained, some of which was rich enough for shipping. No definite vein or ledge, however, was found. In the NW. ¼ sec. 11, about three-fourths of a mile northwest of the prospects described, a 3 or 4 foot bed of quartzite containing disseminated siderite, together with galena, sphalerite, pyrite, and chalcopyrite, is exposed in a tunnel 30 feet long. This mineralized bed is overlain by a fissile shaly bed which is not mineralized. It lies nearly horizontal and its outcrop can be traced for some distance along the hillside. No definite indication of a mineralized fracture or fissure has been found here, though near the end of the tunnel there is a zone 4 or 5 feet wide in which the rock is broken by many parallel joints which strike N. 20° W. and are nearly vertical.

About 1½ miles west of these prospects there are a number of locations on the headwaters of the West Fork of Slate Creek and near the southwest corner of sec. 9. In one prospect hole examined mineralized quartzite containing galena and sphalerite similar to that already described was found. No definite indications of any mineralized fracture or fissure were seen here by the writer, but from the testimony presented at the hearing it is evident that a heavy "iron cap" consisting mainly of vein quartz and botryoidal hematite has been discovered and partially developed. This material when assayed showed small values in silver and gold, though it contains no unaltered galena. Small amounts of galena were also found in several other prospect holes in this vicinity, in which the relations are similar to those already described and which need not therefore be mentioned in detail.

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[a] Ransome, F. L., op. cit., pp. 293–298.

In T. 45 N., R. 6 E., about 10 miles in a direct line S. 60° E. from the prospects just described, a similar occurrence of galena in quartzite was examined. Here a gray quartzite containing siderite and galena lies nearly horizontal, but is cut by a number of parallel joints which strike N. 70° W. Considerable prospecting was done several years ago in sec. 3, T. 45 N., R. 4 E., and two of the old tunnels are still open. The rocks here are broken by a system of vertical joints which strike N. 70° E. There is no evidence of displacement along these joints, but several of them contain quartz veins, the largest of which, about 6 inches wide, thins down to nothing in a distance of 40 feet. The quartz is honeycombed with iron-stained cavities and contains some weathered pyrite. Prospectors report that the unweathered ore contained galena, and that there was also a large ledge or "blow-out" of galena ore exposed in the creek bed at a point now covered with gravel. Galena-bearing rocks were reported by many witnesses from other localities, and though most of these were not examined by the writer it may reasonably be believed from the evidence presented that such minerals are widely distributed. As far as observed the rocks in which these ores occur belong in the Cœur d'Alene series, and probably for the most part in the Wallace formation. The prevailing strikes, both of the bedding planes and of the most definite systems of jointing and cleavage, are approximately N. 70° W. Samples of such ores taken from seven different localities were assayed for lead and silver, and though none of them were found to carry values sufficient to make them commercial ores under present conditions, all showed the presence of more than traces of these metals in the average proportion of one-third of an ounce of silver to 1 per cent of lead. In the Cœur d'Alene district this proportion is about one-half an ounce of silver to 1 per cent of lead, and it is evident, therefore, that these ores are somewhat lower in silver than those of the Cœur d'Alene district. The only sample collected by the writer which was tested for gold was found to carry 0.02 ounce of gold to 1 per cent of lead. From the testimony of a number of other witnesses who have had analyses made of ores from this region it seems to be true that generally these ores are richer in gold than the lead-silver ores of the Cœur d'Alene district.

COPPER DEPOSITS.

Copper ores, some of which are in valuable deposits, are well distributed over the whole district. These probably occur in several of the Cœur d'Alene formations, and although they are all connected with definite fractures or lines of faulting they present some variety in their occurrence. The most important series of prospects is found in a belt about 6 miles wide extending for about 16 miles southeast from Stevens Peak along the Montana-Idaho boundary. A great deal of development work has been done in this belt, since it is easily accessible from points on the Northern Pacific Railway. The ore bodies here are deposited in fault fissures which strike approximately east and west. Although the intrusive masses of diabase already mentioned are common in this vicinity, none of the copper-bearing ledges have been definitely connected with them. These ledges are for the most part contained in rocks which probably belong to the Wallace formation and the displacements along the fissures are probably not very great. Croppings of the veins are usually indicated by heavy "iron caps," which sometimes project above the surface, forming what are locally called "blow-outs." The gossan usually consists of breccia derived from the wall rocks cemented by hematite and limonite. It usually contains the copper carbonates, malachite and azurite. At greater depths the ore is still mixed with broken country rock, but the vein matter consists of calcite, siderite, and some quartz, with more or less sulphides of copper and iron. In one instance galena and chalcopyrite are present in nearly equal amounts, but usually galena is not present. Nearly all these ores carry considerable gold.

The Bald Mountain ledge, situated near the north line of T. 46 N., R. 7 E., may be taken as a typical example of the copper-bearing veins in this belt. This ledge is developed by a tunnel for nearly 1,000 feet. It strikes approximately east and west, but does not extend in an exactly straight line, and dips to the north at an angle of about 60°. The ledge matter varies in width from 1 to 8 or 9 feet and consists of brecciated quartzite similar to the walls, cemented with vein matter consisting of quartz, calcite, and siderite, in which sulphides of copper and iron are contained. At one point there is a definite ore shoot several feet thick, extending for 100 or 200 feet along the tunnel. The ore in this shoot consists of nearly pure siderite containing chalcopyrite scattered through it. When assayed a specimen of this ore was found to contain 1.5 per cent of copper, 0.02 ounce of gold, and 1 ounce of silver per ton. At the face of the tunnel the ledge consists of brecciated country rock cemented together by quartz, with some calcite and siderite. A specimen of the most promising ore in the face was assayed, showing a trace of gold and 1.42 per cent of copper. The croppings of this ledge are said to be easily traceable on account of a heavy "iron cap." Some distance beyond the end of the tunnel an ore shoot which promises to be considerably richer than that described has been found and toward this the tunnel is being extended.

The Monitor mine, also in T. 46 N., R. 7 E., and about 2½ miles southeast from the Bald Mountain, is the only one which has actually produced ores on a commercial scale. It is connected with the railroad at Saltese, Mont., by a wagon road 5½ miles long. The developments have not yet progressed far enough to tell definitely either the dimensions of the ledge or the direction of its strike, but it is evident from the developments already made that it is of the same type as the Bald Mountain ledge already described. The strike is said to be nearly east and west and it dips about 80° N. The ore consists of a great deal of brecciated material cemented by vein matter and is evidently deposited along a fault. That the movement has continued since the deposition commenced is shown by slickensiding of some of the ore. The mine is developed by a shaft to a depth of 300 feet, and by short tunnels on the 100, 200, and 300 foot levels. Above the 100-foot level nearly all of the ore is oxidized and consists of hematite and limonite mixed with the carbonates of copper. Below a depth of 125 feet, however, there are no carbonate ores, and the principal copper-bearing mineral is chalcopyrite associated with pyrrhotite. Evidently the main shaft of the mine has been sunk directly on a rich ore shoot which cropped at the surface. The ore body is probably at least 10 feet wide, though the walls are not yet well defined and its extent has not been determined. Ores from this mine carry considerable gold as well as copper. In the oxidized upper portion the gold value is often as high as $12 per ton, but below the 60-foot level it ranges from $3.60 to $8 or $9 per ton. The copper ore shipped ranges from 10 to 30 or 40 per cent. This mine was discovered in 1897 and the first shipment of ore was made in 1900. In all, about 500 tons of ore have been sent to the smelter. The ore is first hauled by wagon 5½ miles to Saltese, Mont., whence it is shipped by rail to Tacoma, Wash.; the total cost of shipping and smelting amounts to nearly $8 per ton. Three hundred tons of the ore netted the owners of the mine $34.85 per ton after the freight and smelting charges were deducted.

In the immediate vicinity of the Monitor mine, both west and south for 6 or 7 miles, copper-bearing ledges have been located which are reported to be of the same general type. One of these, known as the Buffalo, crosses the Montana-Idaho boundary and was examined by the writer. This mine or prospect is about 8 miles southeast of the Monitor, and is being developed on the Montana side, where it is reported to carry good prospects in copper. Where it crosses the divide the vein is exposed in an open cut. It is here several feet wide and the ore consists for the most part of spathic iron containing very little, if any, copper or gold.

Other locations in this belt where development is in progress and in which the general relations are believed to be similar to those described are known as the Park, Springfield, Champion, Wonderful, Eagle, Bullion, North Star, Alpino, Richmond, Leroy, Wampum, and Kootenai Giant claims or groups of claims. Outside of this belt, which lies along the

Montana boundary, the copper prospects are scattered and undeveloped. Several copper-bearing ledges along St. Joe River below the crossing of the De Borgia trail are reported by prospectors, but these have not been examined by the writer, though specimens of copper ore consisting of chalcopyrite and quartz were found in the gravels in St. Joe River near the point where the De Borgia trail crosses. A rather promising copper prospect in which the ore consists for the most part of carbonates is reported from T. 42 N., R. 8. E., near the southern boundary of this district.

In T. 45 N., R. 3 E., there is a group of copper prospects, some of which have been partially developed. They occur for the most part in a white quartzite, which may be identical with the Revett formation, and near some masses of intrusive granite. The best known of these, called the Black Prince, is situated at the mouth of Black Prince Creek, in section 10, and is developed by two short tunnels, but it has been abandoned for several years. The ore body consists of brecciated quartzite, having the interstices filled with vein quartz which contains a considerable amount of bornite, chalcopyrite, and pyrite. Some well-defined joints, one of which seems to mark the wall of the ore body, strike N. 65° W. On the dumps of this tunnel there are several tons of rather promising ore, but the face of the tunnel shows only narrow stringers of ore, surrounding the fragments of quartzite. Two samples, one taken from the face of the tunnel and the other from the surface croppings, were assayed, showing the presence of copper and gold, but no trace of silver. Copper-stained débris has been found for several miles northwest from the Black Prince, and near Big Creek, which joins St. Joe River in section 5, there are several partially developed prospects, some of which promise to yield copper ores, while others may lead to deposits of lead and silver or gold. The prospects examined show a large deposit of gossan, in which neither galena nor stains of copper were recognized. Assays of samples taken at random showed small amounts of gold and silver, but no trace of copper. Prospectors interested in the development of these claims report that the assays which have been made range from 80 cents to $10.75 in gold. The development has not progressed far enough to show the course of the veins. Near them, however, there are outcrops of breccia indicating a fault which strikes N. 70° W., and it is probable that the course of the heavily mineralized deposits just described will be found to be parallel with it. To the north of this place, for several miles along Big Creek, in T. 56 N., R. 3 E., there are reported to be prospects showing carbonates of copper, but these were not examined by the writer.

In T. 43 N., R. 4 E., considerable prospecting has been done on a vein carrying pyrite, chalcopyrite, and bornite in white quartz. From the testimony of other witnesses this seems to be a well-defined vein traceable for 400 or 500 feet in a northeast-southwest direction, and contained between walls of schistose quartzite, which is probably equivalent to the Revett quartzite of the Cœur d'Alene district. The vein is reported to be about 10 feet wide and is developed by several open cuts and a tunnel 36 feet long. An average sample of the ore taken across the ledge is said to have yielded $2.48 in gold, silver, copper, and lead. A picked sample which was assayed for the writer was found to contain a trace of gold, 0.8 ounce silver, and 2.1 per cent of copper. Copper ores have been reported by prospectors from many other parts of this region, but except in the localities described there have been no attempts at development and the prospects were not examined.

PLACER-GOLD DEPOSITS.

This region has been prospected more or less for placer gold for the past forty years, and although there are placer-mining districts a short distance away on nearly all sides, attempts to locate valuable deposits of this kind have here been unsuccessful. In the surrounding regions placer gold is mined at Murray[a] in the Cœur d'Alene district, at Tyson, about 10 miles west of the southwest corner of this district; near Dent and Orofino,[b] on North Fork of Clearwater River, from 10 to 20 miles south; at Moose Creek,[a] Cedar Creek, and St. Joe basin, near the southeast corner of this district; and at Deer Creek, near the northeast boundary.

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[a] Ransome, F. L., op. cit., pp. 299-300.

[b] Lindgren, Waldemar, op. cit., pp. 84-85.

On the headwaters of St. Joe River a small placer district, locally called the St. Joe basin, is partly within the area covered by the map, Pl. IV, though the protest regarding that part of the classification has been dismissed. Owing to the short time available for field work and the fact that it is outside the area involved in this hearing it was not examined by the writer. Gold was discovered as early as 1870, and a few men have mined here continuously for the past ten years, but no large amounts of gold have been obtained. The district is said to be 25 miles distant from Iron Mountain, Montana, from which place a wagon road leads up Cedar Creek to within a few miles. Cedar Creek in Montana, a tributary of Missoula River, and Moose Creek in Idaho, a tributary of Clearwater River, are placer-bearing streams in the same vicinity. St. Joe basin, so called, is described as a gravel-covered flat several miles long, containing about 320 acres, at the head of Middle Fork of St. Joe River. The auriferous gravels here are deep and owing to a reef of bed rock near the lower end of the deposit it has been impracticable to drain them, so that except around its rims the basin deposit has not yet been worked. Medicine, Wisdom, Sherlock, and Rocker creeks are small placer-bearing streams tributary to the basin, and probably contributed much of the gold in the larger deposit. The bed rock along these streams is reported to be quartzite cut by "seams of quartz and talc,"containing free gold. Coarse colors of gold are found in the gravels of St. Joe River as far down as the crossing of the De Borgia trail, but attempts to locate valuable deposits below the basin have not been successful. The gravels along St. Joe River through its whole length contain large quantities of garnets and of black sand consisting of magnetite and ilmenite.

Near the western boundary of this district, in T. 45 N., Rs. 2 and 3 E., there are deposits of auriferous gravel along Mica Creek, from which it is possible that miners could make wages by sluicing. Attempts at placer mining have been made at several other places, but none of these have been at all successful.

GOLD-QUARTZ VEINS.

It has been shown that some of the ledges described as copper deposits also carry considerable amounts of gold. Near Wards Peak, however, in the eastern part of the district, and from that point southward for several miles, the rocks are cut by distinctly gold-bearing quartz veins, some of which are undoubtedly of economic value. Two such veins southeast of Wards Peak are partially developed and were examined. The country rock here consists of a sericitic slate or quartzite, which is probably equivalent to the Prichard slate of the Cœur d'Alene district. It is cut by quartz veins, which extend more nearly north and south than east and west. One of these, called the Gold Mountain vein, has a width of about 15 feet; it strikes N. 20° W. and stands nearly vertical. It has been traced northwestward about one-fourth of a mile and is there exposed in the face of a steep cliff. Two large stringers parallel with the bedding of the slate lead off to the west from the main vein. The ore of the Gold Mountain lode consists for the most part of white quartz, but near one of the walls it is heavily mineralized with pyrite in large tubes. Where developed by the shaft this pyrite is altered to hematite or limonite, in which the free gold can often be seen by the naked eye. Picked samples of this ore when assayed showed values exceeding $60 in gold to the ton, while average samples carefully taken across the whole width of the ledge are reported to yield about $10 in gold per ton.

The Revenge lode, which lies about half a mile west of the Gold Mountain, strikes a little east of north. It has a width of about 5 feet and its ore, like that of the Gold Mountain ledge, consists of weathered pyrite contained in white quartz. This pyrite, however, is much more evenly distributed through the quartz than is the case in the Gold Mountain ledge. Picked samples of this ore yielded when assayed about $40 in gold to the ton. It is reported that average samples indicate that the ore will run not far from $10 per ton.

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[a] Lindgren, Waldemar, op. cit., p. 108.

Both these veins appear to be widest where they cut a diabase dike 100 feet wide, which extends N. 80° E. The effect of the dike seems to be purely mechanical, since away from it the veins show a tendency to divide up into stringers.

A vein called the Mother lode, situated on a spur of Wards Peak about half a mile north of the boundary, consists at the surface of two veins, each about a foot thick, which come together in the face of the tunnel 25 feet in from the surface. Both these veins are cut by a horizontal fault having a throw of about 1 foot.

Similar ores occur about 2 miles north of the boundary around Eagle Peak, and about 5 miles north of the boundary, in a mine owned and formerly operated by the Deer Creek Mining Company. This mine is equipped with a small stamp mill, which was idle during the past season. The company also controls some placer deposits along Deer Creek, on which development work was in progress in September, 1905. The gold in the quartz ledges of this neighborhood is free as far as the ledges have been developed. It seems probable, however, that in depth it will be found refractory and will require concentrating and smelting.

Fragments of quartz similar to or resembling that at Wards Peak were found strewn on the surface along the De Borgia trail to the southern limit of the area examined. In this distance one large quartz vein 10 feet or more in width and several smaller veins were seen. A sample from the large vein was found to contain traces of gold and half an ounce of silver to the ton. Only one of the smaller veins was sampled and assayed, but this was found to contain no traces of gold. In the altered quartzites and schists found in the southwestern part of the district a few small quartz veins were noted. One of these, which cropped out along the trail near Slide Rock Peak, in T. 44 N., R. 3 E., is about 1 foot thick and lies between the bedding of the country rock, which here probably belongs to the Prichard formation, though it is altered practically to a mica-schist. A sample taken from this vein when assayed yielded a trace of gold and no silver.

Very little prospecting has been done in the southern part of this district, and no prospect holes were seen by the writer. It is remote from settlements and difficult of access. The obvious occurrence here, however, of small quartz veins carrying traces of gold seems to warrant the belief that there may be some gold-bearing veins of economic value.

RÉSUMÉ AND CONCLUSION.

This region is practically unexplored and undeveloped, though its geologic and topographic conditions are quite similar to those of the Cœur d'Alene mining district, to which it is adjacent. Prospects, more or less promising, of lead-silver, copper-gold, and gold ores have been found at many widely distributed localities, most of which are along the trails or adjacent to the larger streams. Commercially, valuable ores have been produced at only one of these localities.

Most of the lead-silver prospects are in the northwestern part, and the ore consists of galena, either distributed through the country rocks or contained in masses of limonite or iron caps, whose relation to the country rock has not yet been determined. These ores average one-third ounce of silver to 1 per cent of lead.

The copper-gold ores are more widely distributed. They occur in definite veins developed along fault fissures, and their outcrops are indicated by gossan stained with copper carbonate. In depth the vein matter consists mainly of siderite, calcite, and quartz, with the sulphides of copper and iron. The proportion of gold to copper varies greatly, though it seems to average about 0.02 ounce of gold to 1 per cent of copper. Most of the development of these veins has been done in a belt a few miles wide near the Montana-Idaho State line, where about 500 tons of high-grade ore have been mined and shipped.

Gold placers of economic value are not known to occur within the area involved in this contest, though prospectors report that fine colors of gold can be obtained from the gravels of many of the streams, and there is a small placer district adjacent to the southeastern part which has produced some gold for the past twenty or thirty years. Gold-bearing quartz veins, some of which are valuable, occur in the eastern and southern parts of the area in controversy. These veins contain free-milling ore at the surface, but will probably become base in depth. No gold ores except those in which copper is associated have been produced on a commercial scale.

Since these lands had already been classified by the United States mineral commission, the burden of proof as to their nonmineral character fell to the railway company. After reviewing the great volume of evidence presented, the officials of the Cœur d'Alene land office have made a report recommending that, with the exception of a few small tracts regarding which there is specific evidence of nonmineral character, the mineral classification be allowed to stand.

COPPER DEPOSITS NEAR LURAY, VA.

By William Clifton Phalen.

INTRODUCTION.

In an investigation of the copper deposits of the eastern United States by Mr. W. H. Weed, the writer was detailed to reexamine several properties in the Blue Ridge region near Luray, Va. The special object of this work was to find additional evidence concerning the genesis of the ores, previous examinations by Mr. Weed having resulted in conclusions wholly at variance with the opinions held by the various companies operating in the region. This paper is based on field observations and careful study of thin sections under the microscope.

Location.—The region treated in the following notes lies at or near the summit of the Blue Ridge, between Page and Madison counties, Va., and along the western foothills of the same a few miles south of Luray, also near the crest of the ridge near High Knob, between Greene and Rockingham counties, some distance to the southwest.

THE ROCKS.

In general, the Blue Ridge in this section is made up chiefly of basalt, but along its western flank at various points may be seen the outcrop of an extensive mass of syenite. On the east flank of the ridge, near the head of Robertson River (Robinson River [a]) and a few miles southeast of Fishers Gap (Milams Gap [a]), in Madison County, there is an intrusion of biotite-granite. Of these rocks the basalt has the more interest in this connection from the fact that it carries the copper ore. It is inferred that this rock is the Catoctin schist of Keith,[b] and that it is coextensive with the South Mountain basalts of Pennsylvania described by Bascom [c] and Williams.[d] According to Keith, the rock is Algonkian in age.

The chief mass of the basalt, or melaphyre, or greenstone, as it has been variously termed, is dense and dark green, except where thoroughly epidotized, when it assumes a lighter-green hue. Its original constituents are not determinable without microscopic aid, save perhaps an occasional phenocryst of olivine. From the facts that bosses of syenite are seen in it in the region near Fishers Gap and that it has been subjected to an intense metamorphism along its contact with the syenite on the west slope of the ridge and wherever the two rocks are contiguous, it is inferred that the syenite is the younger of the two rocks. This inference is strengthened by the perfectly fresh, holocrystalline character of the syenite at the immediate contact and by the lack of weathered fragments or bowlders of the syenite in the basalt. This contact metamorphism has resulted in a more or less schistose rock, quite different from that of the main mass, which, in this particular district, is not regionally schistose. The basalt is regarded as more recent than the granite of the east side, from the metamorphism exhibited by the latter along the contact. This has resulted in a gneissoid belt several feet in width. These conclusions regarding the relative ages of the igneous rocks have been deduced from the examination of a limited number of contacts and are given subject to revision, as the writer is aware of their somewhat doubtful character.

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[a] Names in parentheses are used locally.
[b] Keith, A., Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 296 et seq.
[c] Bascom, F., Bull. U. S. Geol. Survey No. 136, 1896, pp. 68 et seq.
[d] Williams, G. H., Am. Jour. Sci., 3d ser., vol. 44, pp. 490–496.

The basalt is comparatively simple and is composed of plagioclase-feldspar, pyroxene, and magnetite, which may be titaniferous, together with olivine and the secondary constituents epidote, chlorite, serpentine-asbestos, quartz, the iron oxides, and leucoxene. The olivine occurs frequently as phenocrysts, sometimes 3 or 4 mm. in diameter, and generally presents a thoroughly corroded periphery surrounding a tolerably fresh nucleus. At times even this has disappeared, leaving a brownish-red mass of iron oxide to mark its former position. The results of the microscopic examination show profound alteration and the original constituents are not readily determined. Of the secondary constituents enumerated above, epidote is by far the most important. Some of this constituent, including part of that seen at the lowest worked levels, has been formed by interreaction between feldspar and pyroxene. The question of its various modes of origin is one of the most interesting chemico-geological problems of the region.

The syenite of the west slope has been referred to the hypersthene-åkerite type of Brögger and is essentially a quartzose augite-syenite. It is a coarse-grained dark rock with the feldspar, pyroxene, and quartz visible to the naked eye. It is made up of the minerals orthoclase, much of which is microperthitic, plagioclase, quartz, hypersthene, diallage, magnetite, apatite, zircon, and microcline, together with the alteration products epidote, chlorite, and sericite. Sometimes this rock is thoroughly epidotized, and then forms that peculiar rock known as unakite.[a]

The granite of the east base of the mountain, near Fishers Gap, is the biotite variety and has not been examined by the writer in thin sections.

THE COPPER ORES.

Developments.—The Blue Ridge in this part of the State is a single ridge composed entirely of igneous rocks. It has been mentioned that of these the basalt carries the copper. The occurrence of copper in this region has long been known. There is a tradition that on the land of the Blue Ridge Copper Company, 1 mile southeast of Fishers Gap, the metal was mined and shipped before the civil war. At the time of the writer's last visit, in May, 1905, an incline 42 feet in depth had been dug by this company about 150 feet above the confluence of the main head forks of Robertson River, and from the foot of the incline a 40-foot drift had been run in a northeasterly direction to intercept a supposed cupriferous zone in the old shaft 100 feet higher on the hill. Before this zone was reached operations were temporarily suspended and drilling had just begun on a third shaft northwest of the old shaft and higher on the hill. It is the company's intention to resume operations at an early date on the drift from the incline, and when the copper-bearing zone is reached to sink the old shaft still lower. A few tons of ore have already been shipped from this property.

The most extensive developments in this part of the State are those of the Virginia Consolidated Copper Company, whose property lies on one of the foothills at the west base of the Blue Ridge about a mile northwest of Ida post-office, 6 miles southeast of Luray. An inclined shaft has been sunk about 300 feet, and at the 80, 120, and 280 foot levels, drifts of varying lengths have been run off. At present (May, 1905) operations are temporarily suspended. It is the intention, however, to continue the shaft at least 200 feet lower. Besides the work of these two companies, more or less prospecting has been done in the vicinity of Stony Man and at the head of Overall Run, 13 miles northeast of Luray. The work seen at the former locality is very old. The most noteworthy instance is the old shaft reported 60 feet deep, but filled with water when visited. Near the head of Overall Run, in Warren County, prospecting on a small scale has been done very recently for Front Royal people on the so-called "Empire vein." Two abandoned shafts lower on the hills than the "vein" indicate that interest in the copper resources of the region was aroused some time ago. Both these shafts, when visited, were filled with water. The more recent, on the R. A. Martin tract, was sunk to a depth of 70 feet by Mr. S. M Boyd, of Philadelphia. It was worked intermittently during 1903 and 1904, work having been suspended at the end of the latter year. The older of the shafts is situated on the F. C. Hartley estate, below and southwest of the Boyd shaft. According to report it was worked over thirty years ago.

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[a] Phalen, Smithsonian Miscellaneous Collections, vol. 45, 1903, p. 309.

At the mines of the High Top Copper Company, near High Knob, about 7 miles southeast of Elkton, considerable development work has been done. In addition to several prospects scattered about the property a shaft has been sunk to a depth of 90 feet and about 300 feet farther down the hill a level has been run in about 50 feet. It is the intention of the company to sink the shaft and continue work in the level until the two intersect, as well as to sink other shafts and run other levels on them on the company's property to the northwest. At the present time the machinery on the ground aggregates 200 horsepower, with compressors and air drills for facilitating the work. It is the intention of the management to add largely to the equipment in the near future. Unfortunately, at the time of the writer's visit to the region (February, 1906) the shaft was filled with water, hence the copper-bearing rock in it could not be studied.

Occurrence.—The ore deposits seen at all of these points are similar in character. The ore usually occurs along joint planes and in fissures and is most frequently accompanied by quartz. It may accompany shear zones, which are a very conspicuous structural feature in the localities visited. At the mines of the Virginia Consolidated Copper Company near Ida, where development has reached the maximum in the region under discussion, it was noted that these shear zones correspond to a system of joint planes in the country rock varying in direction within the limits S. 4° W. and S. 25° W. A similar though not so close a relationship between the strike of these shear zones and a prominent system of joints was observed at the property of the High Top Mining Company. Usually the alteration of the country rock has reached its maximum in close proximity to these shear zones, or accompanying them. Similar zones of alteration were seen at the Blue Ridge Copper Company's workings near Fishers Gap, but development had not proceeded far enough to systematize them.

Near these shear zones the country rock is decidedly epidotized. Chlorite has also formed as well as quartz and feldspar, an association in the case of the last two minerals indicating the action of ascending thermal agencies. Some chalcopyrite and bornite may be found accompanying the quartz and feldspar. The copper sulphides are not confined to the veins near or in these shear zones, however, but occur in the mass of the basalt as well. The surface indications in the region lead to the conclusion that the ore deposits are irregular in occurrence, that the alteration of the country rock has been rather general, and that, although it may prove to be, as a rule, more marked along the major joint planes and in the shear zones, it also probably occurs along the minor joints and the innumerable cracks in the rock.

Origin.—Besides the alteration, the weathering of the rocks has resulted in the production of quartz and calcite, which occur as fillings along the joint planes, sometimes as mere films, locally swelling into lenticular masses, which may end abruptly or zigzag in the most irregular fashion through the rock. The main masses of copper ore are found generally associated with these secondary minerals which have resulted from weathering. This ore is in the form chiefly of native copper and cuprite, with small amounts of malachite and azurite. From their mode of occurrence these fillings and lenses are believed to be veins. At the Virginia Consolidated Copper Company's mine they appear to be developed on a larger scale comparatively near the surface and to diminish in extent with depth. From the fact that the mines near Ida tend to become dry with depth, it is believed that the moisture in the workings is chiefly of meteoric origin and moreover has been instrumental in producing the main ore deposits. The disseminated sulphides have probably furnished much of the ore, which has been segregated along the fissures and joint planes in the rock and has perhaps been dissolved and redeposited many times before finding its present position. Although ascending waters may have been instrumental in bringing up a portion of the sulphides, such as the chalcopyrite in the quartz veins associated with the shear zones, there is no evidence that this sulphide will increase in depth or that it occurs in large bodies. If this concentration by descending surface waters be the true origin of the workable bodies, the ore must be sought near the surface and will tend to diminish in depth, a conclusion in accord with field observations at the localities studied.

Finally, it may be mentioned that these occurrences are examples of the "Catoctin" type of copper deposits of the southern United States, which have been described by Weed.[a]

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[a] Trans. Am. Inst. Min. Eng., vol. 30, 1900, pp. 498-504.

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TIN, QUICKSILVER, PLATINUM, ETC.

TIN IN THE FRANKLIN MOUNTAINS, TEXAS.

By G. B. Richardson.

Introduction.—Since the publication of Mr. W. H. Weed's report on the El Paso tin deposits[a] the geology of the Franklin Range, in which the ore occurs, has been further studied, and some additional prospecting has been done. In view of the scarcity of tin in the United States, it seems desirable to outline the conditions as now known in the western Texas tin field.

Topography.—The Franklin Mountains are the southern extremity of the long, narrow range, known locally by different names, that extends southward from the Rocky Mountains east of the Rio Grande as far as El Paso. The Franklin Mountains are 23 miles in length, 15 of which are in Texas, average 3 miles in width, and rise 3,000 feet above the adjacent lowlands, culminating in North Franklin Peak, whose elevation is 7,140 feet. The western face is relatively little eroded and constitutes a dip slope. The eastern side, on the contrary, is much dissected and exposes cross sections of the rocks. The range is practically bare of vegetation, its lower slopes only being occupied by desert growths, among which greasewood, lechuguilla, sotol, and prickly pear are prominent. The rocks, therefore, are plainly exposed, except where covered by local accumulations of débris.

General geology.—The accompanying geologic map (fig. 7) outlines the distribution of the different formations in the Franklin Mountains. The rocks have been studied in detail only in the eastern part of the range in the area lying within the El Paso quadrangle, west of which only general conditions are shown. For the present purpose it will not be necessary to do more than outline the broader features of the general geology, since details will be published in the forthcoming El Paso folio.

The oldest rocks in the Franklin Mountans are of pre-Cambrian age and include two distinct formations. The lower one consists of about 1,800 feet of light and dark quartzites and subordinate slates, which have been cut by a few thin diabase dikes. These rocks are succeeded by a bed of rhyolitic conglomerate, which attains in places a thickness of 400 feet, above which is a mass of porphyritic red rhyolite over 1,000 feet thick. About 300 feet of indurated, fine-textured sandstones carrying Upper Cambrian fossils overlie the rhyolite and contain rounded pebbles of the latter in the basal bed. The sandstone is succeeded by a considerable thickness, amounting to 5,000 feet or more, of massive gray limestone, which lithologically is difficult to subdivide but paleontologically is separable into four main parts. These are referred to the Lower and Upper Ordovician, Silurian, and Upper Carboniferous, the approximate thickness of limestone assigned to each division being, respectively, 1,000, 400, 1,000, and 3,000+ feet. The Devonian and Mississippian are not represented by sediments. All of these rocks from the pre-Cambrian to the Carboniferous are structurally conformable and dip westward at angles varying in different parts of the range from 20° to 45°. No sediments of early Mesozoic age are present, but Cretaceous strata, including the Washita and Benton groups, occur in isolated areas west and south of the range. The adjacent lowlands are underlain by gravel, sand, and clay to a depth of over 2,000 feet.

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[a] Bull. U. S. Geol. Survey No. 178, 1901.

A considerable amount of granite occurs in the Franklin Mountains along the eastern base, chiefly associated with lines of faulting. The granite is a post-Paleozoic intrusion and is important as the rock in which the tin ore occurs. It is a medium to coarse textured variety, superficially reddish in color, and weathers readily to a coarse sand. Fresh exposures are rare but from the tin prospects specimens are obtainable, a partial analysis of one of which by E. C. Sullivan, of the United States Geological Survey, gave:

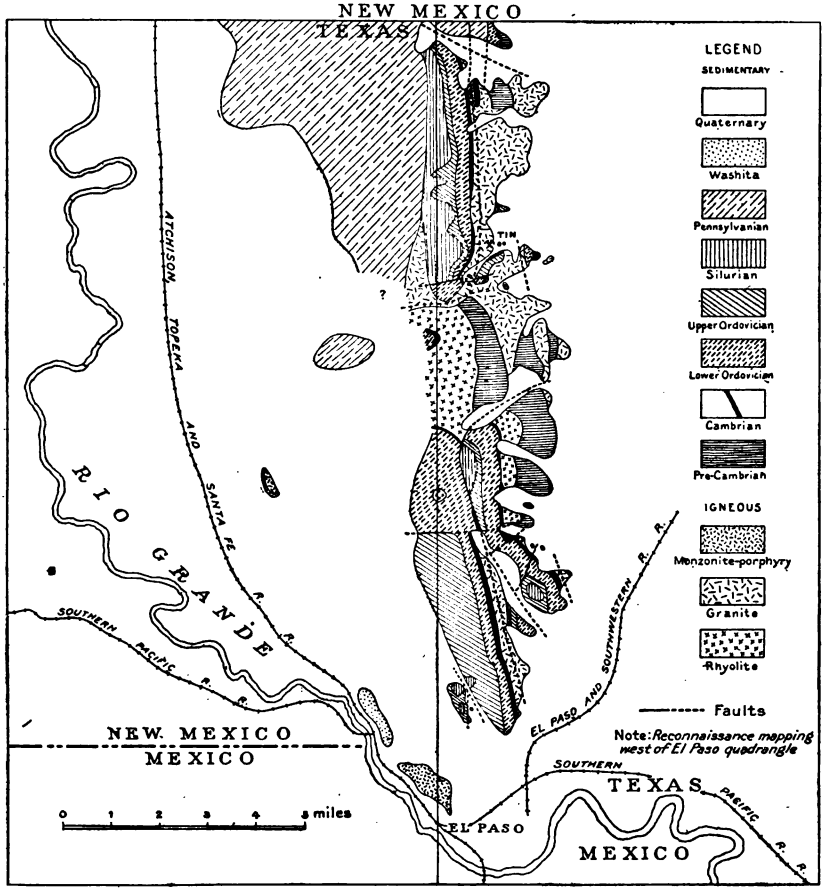

FIG. 7.—Geologic map of the Franklin Mountains, Texas.

Partial analysis of granite from tin prospect in Franklin Mountains, Texas.

	Per cent.
SiO_2	73.76
CaO	.81
K_2O	5.66
Na_2O	3.64

The alkalies are slightly higher and the lime lower than in normal granite. The rock is composed of preponderating quartz and feldspar, the latter in excess, with subordinate biotite, rare hornblende, and bits of magnetite. The feldspars are orthoclase and albite, commonly present in the minutely intergrown form known as microperthite. A small area of monzonite-porphyry of post-Comanche age occurs near the Rio Grande.

Two prominent sets of joints, striking in general north-south and east-west, traverse the rocks of the Franklin Mountains, and the distribution of the strata reveals several large faults in both of these directions. The main faulting is approximately parallel with the north-south trend of the range, and as the strata dip toward the west the internal structure shows a series of tilted blocks. Whether the whole range is a large block limited on the east by a fault, although suggested by the topography, has not been determined. The fact of recent movements is proved by the presence of minor faults in a sand bank in the northern part of El Paso. These displacements follow the same trend as the principal faults in the mountains.

Occurrence of the ore.—Prospecting has revealed the presence of tin ore in a small area in granite at the eastern base of the Franklin Mountains about 12 miles due north of El Paso, but not enough development has been done to make possible generalizations of much value concerning its occurrence.

Reference to the map brings out the fact that the prospect lies adjacent to one of the main north-south faults. Here the displacement amounts approximately to 3,000 feet, shown by the fact that the Silurian limestone which outcrops on the crest of the range occurs on low hills east of the prospect. The exact position of the fault plane is obscured by the granite, which is intrusive along it. Other near-by faults are also indicated on the map, and there is evidence of minor displacements. The joint planes present in the rocks throughout the range are here characteristically developed, and the tin occurs as cassiterite, associated with quartz veins along the east-west joints in the granite. The joints along which the veins occur strike transversely to the trend of the range, and the veins dip perpendicularly or at high angles either northward or southward. The greatest distance that any of these veins has been traced along the surface is about 1,000 feet, and one has been followed downward to a depth of about 50 feet. The quartz is massive, white, and of variable thickness, varying from a fraction of an inch to 2 feet, irregularly thickening and pinching out. Locally the walls of the vein are plane and the contact with the country rock is smooth. At other places the veins grade off into the granite. The mineralized zone at the greatest width measured is not over 6 feet thick and ranges from this to 0. Sections across the zone show irregular veins of quartz in the granite, which is minutely seamed with joint cracks. Cassiterite occurs in the vein quartz and more abundantly immediately contiguous to it. In the vein quartz the oxide of tin occurs, both in bunches and irregularly disseminated, intergrown with the quartz. More concentrated deposits of cassiterite occur intimately associated with the quartz and feldspar of the granite adjacent to the veins. Mineralization apparently occurs only contiguous to the veins and fades out a few inches from them. The cassiterite is present in crystals less than a tenth of an inch in size, both twinned and in simple tetragonal forms, and it also occurs massive. Specimens of nearly pure cassiterite weighing several pounds are reported to have been obtained from this locality, but the area has been well picked over and at present, without further work, good specimens are difficult to find. The present stage of development, therefore, is unfavorable for detailed study. Minerals usually associated with tin apparently do not occur abundantly here. Weed reports the occurrence of wolframite and of a single grain of tourmaline. Fluorspar is sparingly present, associated with the cassiterite, which occasionally includes it. Some pyrite is present, and limonite occurs superficially through the veins and locally forms a selvage between them and the granite. No dikes have been observed in the granite in the vicinity of the tin prospect, although a specimen in the office of Judge C. R. Morehead, one of the owners of the property, suggests that pegmatite may be present. On the crest of the granite ridge 2½ miles southeast of the main tin prospect there is a vein of common garnet, with no associated vein minerals, parallel to the east-west joints in a coarse-textured phase of the granite. The vein varies from an inch to a foot in width and is at least 200 feet long.

Development and future.—A frame cabin near a feeble seep spring about a quarter of a mile southeast of the main prospect serves as a working base. But for a considerable supply of water, wells must be sunk on the mesa east of the mountains, where an abundant amount is available, reached by wells between 200 and 300 feet deep, in which the water rises to about 180 feet from the surface. The El Paso Southwestern Railroad crosses the mesa 6 miles from the prospect.

The principal development of this property has been recorded by Mr. Weed. The ore was dicovered in 1899 and at the time of his visit, in 1901, the three veins then known had been exposed for several hundred feet along their length and a few pits had been sunk, the deepest being 50 feet. Little work appears to have been done on these veins since then, although they have been much visited. In 1904 two small occurrences of tin ore associated with quartz were found about half a mile apart, the farthest being between 1½ and 2 miles north of the old workings. These new occurrences are similar but smaller than those first found. Development has not gone further than barely scraping the surface along the veins for a few hundred feet and sinking a few shallow pits. The work reveals irregular streaks of quartz, with associated cassiterite, varying up to 2 inches in thickness, in veins parallel to joints transverse to the trend of the range, in much decomposed and broken granite. Locally slickensided surfaces of granite occur. In a pit about 8 feet deep on the northernmost vein the quartz was found to fade away at a depth of 4 feet below the surface.

Present developments do not warrant a prediction of the future of this field; it may or may not prove to be of considerable value. Some of the ore is of excellent quality and the chief question concerns its abundance. This can be determined only by further development and prospecting. In seeking new localities for similar occurrences, the entire granite outcrop might well be examined, and it should be borne in mind that the veins thus far found do not follow the contacts of the granite with the adjacent rocks, but occur along the east-west set of joints.

INVESTIGATION OF BLACK SANDS FROM PLACER MINES.

By David T. Day and R. H. Richards

INTRODUCTION.

One of the earliest notes concerning the occurrence of gold in California[a] points out the probable occurrence of gold in the black sands of the Pacific seacoast, and also points out the difficulty in the separation of the grains of gold from the accompanying heavy minerals.

Among the early prospectors for gold in California this difficulty of separating gold from black sands was recognized and the black sands were avoided. Some account of the minerals making up these sands was given by B. Silliman,[b] who showed that the black sands of Butte County, Cal., contained platinum and iridosmine, magnetite, zircon, chromite, garnet, rutile, diamond, topaz, epidote, pyrite, and limonite. This is one of the earliest references to the occurrence of platinum on the west coast. Following Silliman, W. P. Blake recognized platinum as of frequent occurrence in the black sands of the California sea beach, between Cape Mendocino and the Oregon line. The attention thus called to the occurrence of platinum resulted in considerable mining designed to extract gold from these sands and frequently a small amount of platinum was saved. The platinum was found to contain also considerable proportions of iridosmium and iridium, for which there was no adequate sale. Only a small amount of iridosmium was bought for the purpose of picking out points for gold pens, the rest having no regular market.

While the knowledge of the occurrence of platinum was extended by the placer miners to Del Norte, Humboldt, Trinity, Siskiyou, and other counties in California, and to Coos, Curry, Jackson, and Josephine counties in Oregon, as well as to considerably richer localities in British Columbia, notably in Granite Creek, a tributary of Tulameen River, little interest was taken by them in saving the platinum, on account of its small value. In 1897, however, a demand suddenly arose for osmium from the Welsbach Light Company, which needed a supply for making the filament of the osmium incandescent electric light. In 1897 and 1898 one of the writers examined various placers in Shasta, Tehama, Trinity, Humboldt, Siskiyou, Del Norte, San Luis Obispo, and other counties in California, in Coos, Curry, Jackson, and Josephine counties in Oregon, and at Granite Creek in British Columbia. From these occasional visits it became evident that even with the new market for the osmium found with the platinum, no adequate supply of platinum would be obtained until a system of separating and utilizing the accompanying minerals in the black sand should be developed.

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[a] Dr. Edward Everett Hale has furnished this reference from Shellrocke's Voyages to California, published in London in 1742.

[b] Am. Jour. Sci., 3d ser., vol. 6, 1873, p. 132.

In the spring of 1905 Congress directed that the report on the Mineral Resources of the United States should include an investigation into the useful values contained in the black sands of the Pacific slope.

PLAN OF PRESENT INVESTIGATION.

EXAMINATION OF SAMPLES.

As the initial step in this investigation the Geological Survey sent a circular letter to the placer miners of the United States, requesting them to send by mail samples, weighing 4 pounds or less, of the heavy-sand residues left in their sluice boxes in placer mining. This met with hearty response and a large amount of material for a preliminary examination was rapidly accumulated. In all, over 2,000 samples have been sent in from 34 States and Territories, and from British Columbia, Mexico, and South America. The following table shows the chief mineral constituents contained in these sands:

Proportion of various minerals in the black sands of the Pacific slope.

[Pounds per ton, except gold and platinum, dollars per ton.]

No. of sample.	Locality from which sample was obtained.	Magnetite.	Chromite.	Garnet.	Olivine.	Monazite.	Zircon.	Quartz.	Mixed minerals.	Gold and platinum.
	CANADA.									
P21	Toronto	561.00	218.00	818.00		13.00	21.00			$230.78
	ALASKA.									
P65	Cape Nome	137.27	[a]63.00	755.00			4.00	905.00	[b]134.10	Trace.
P109	Dominion Creek, Yukon Territory	1,088.00	180.20	632.50			.83	68.82	28.88	411.90
	CALIFORNIA.									
	Del Norte County:									
P99	Crescent City	480.78	209.38	503.13	574.16	56.03	43.55	132.21		.24
P100a	Gilbert Creek, north of Smith River	50.55	48.40	23.86	72.93	.12	.97	1,035.29	768.60	
P100b	Smith River	840.57	508.96	83.30	366.92		17.45	237.91	27.50	[c]2.45
	Humboldt County:									
P89a	Gold Bluff	244.55	75.18	171.57	818.60		16.94	593.60	98.65	6.01
P89b	Do	469.44	103.15	435.26	665.84		16.70	309.84		
P89c	Do	103.11	20.77	69.63	836.00		3.65	800.30	166.80	1.19
P130	4 miles north of Upper Gold Bluff	25.01	1.39	8.36	2.58		.18	979.64	982.50	Trace.
	Mendocino County:									
P103a	Fort Bragg	4.61		1,874.00	18.74		34.49	36.14	31.43	[c].11
P103b	Do	3.60	4.09	1.87			5.77	536.50	1,447.20	[c].17
P95	Sacramento County: Sacramento Valley	356.00	1,121.00				316.90	93.99	108.40	144.33
P120	San Mateo County: Beach	356.60	1,022.29	14.20	[d]290.00		110.40	215.70		Trace.
P27	Yuba County: Marysville	562.00	[e]122.00	10.70	176.00	Trace.	3.00	714.00		.97
	IDAHO.									
	Ada County:									
P36	Boise	26.40	200.80	709.10		219.60	231.40	579.40		1.03
P81a	Do	946.20	51.35	554.20	227.40			220.30		12.50

[a] Ilmenite.
[b] Includes rutile.
[c] No platinum.
[d] Includes other basic igneous minerals.
[e] Includes ilmenite.

Proportion of various minerals in the black sands of the Pacific slope—Continued.

No. of sample.	Locality from which sample was obtained.	Magnetite.	Chromite.	Garnet.	Olivine.	Monazite.	Zircon.	Quartz.	Mixed minerals.	Gold and platinum.
	IDAHO—continued.									
	Ada County—Continued.									
P111a	Boise	a 1,092.90	b 646.30				100.50	20.38	139.90	173.40
P111b	Do	513.30	b 951.00				23.30	281.30	231.20	7.29
P111c	Do	782.70	b 746.10				21.13	292.40	157.60	c 14.71
P105	Do	3.21	b 3.62	10.21			.29	1,606.00	376.50	c .78
P113	Do	f 7.43		1.19	.96		.10	1,502.55	487.41	
P81b	Bingham County: Snake River	35.80	b 8.73	8.23	30.45		1.19	1,185.52	729.21	c .40
P74	Custer County: Robinson	886.50	616.70	452.30			d 32.87	7.94		7.22
P107	Elmore County: Wood Creek, Pine Grove mining district	1,721.00	e 221.71				5.50	51.77		Trace.
	Lemhi County:									
P31a	Arnett Creek, Leesburg Basin	959.60	832.80	116.80		.45	1.55			c 86.81
P31b	Camp Creek, Leesburg Basin	1,290.00	474.20	55.99	14.00		.60			Trace.
P31c	Ward's Gulch, Leesburg Basin	747.90	859.00	128.70		5.54	60.89	73.00		c 43.54
P31d	Richardson Bros., Leesburg Basin	433.20	477.20			10.89		65.33		c 2.69
P31e	Placer diggings, Leesburg Basin	1,939.00	.91	4.20		.50	.86	8.00		
P66	Leesburg	a 1,807.20		37.04		20.38		135.18		6.63
P40	Lincoln County: Shoshone	174.80	15.17	80.67		26.34	46.09	1,441.00		c 26.33
P93	Nez Perces County: Salmon River	981.10	688.00	113.30	36.89	46.63	122.40	12.03		c 234.34
P64	Shoshone County: Dent	28.26	1,336.00	307.60		283.40		45.72		
P25	Washington County: Meadows	629.40	564.10	Trace.		123.80	392.50	232.50		9.64
P85a	Oneida County	9.00	b 1.80	8.40	18.00			1,335.30	628.00	Trace.
	MINNESOTA.									
P71	Swift County: Benson	869.00	38.28	717.80	269.80		35.57	70.36		26.22

a Includes hematite.
b Includes rutile.
c No platinum.
d Includes trace of cinnabar.
e Includes ilmenite and titanite.

Proportion of various minerals in the black sands of the Pacific slope—Continued.

No. of sample.	Locality from which sample was obtained.	Magnetite.	Chromite.	Garnet.	Olivine.	Monazite.	Zircon.	Quartz.	Mixed minerals.	Gold and platinum.
	MONTANA.									
	Custer County:									
P147a	Miles City	11.29	74.00	21.60	119.00		2.40	1,266.00	578.00	[a] .11
P147b	Do	7.26		2.00	122.00		8.00		1,868.00	Trace.
P91	Powell County	1,779.00	17.00	128.00		16.33	.80			[a] 10.31
	NEVADA.									
	Ormsby County:									
P35	Carson City	1,387.00	485.60	41.90		29.47	21.32	9.08		[a] 7.44
P75	Do	1,190.00	168.70	353.60		5.35	80.76	5.00		8.78
	OREGON.									
	Baker County:									
P98	Durkee	486.40	868.60	308.70	119.80		62.38	155.00		[a] 139.40
P84	Do	435.80	126.00	1,000.00	250.70			187.40		[a] 2,325.00
P26	Sumpter	1.21	.56	29.75	11.70	1.05	.01	1,672.31	285.50	.43
P32	Clatsop County: Clatsop Beach	537.50	43.50	137.00		.43	.61	54.80		
	Coos County:									
P92	Johnson Gulch	656.70	261.70	842.10	2.60		1.10	209.70	25.61	[a] 704.67
P443	Marshfield	23.00	[b] 467.70	29.39			36.52	1,200.00	243.48	2.21
P102a	Beach, Randolph district	11.35	45.58	2.61	.05	.98	6.94	.15	1,969.00	8.78
P102c	Do	22.63	216.71	698.22	219.56	.15	46.86	794.95	1.87	[a] 1.46
P102d	Do	20.59	583.24	741.93		.02	45.46	240.29	368.65	
P102e	Do	11.80	202.57	168.22	221.84	.03	16.44	1,378.43	.03	
P102f	Do	29.75	893.89	382.29	171.31		51.80	413.54	57.34	[a] .56
P102g	Do	15.60	235.66	164.32			22.61	1,295.40	265.00	28.70
P101	Whiskey Run, 7 miles north of Bandon	4.55	5.02	2.22	71.23		.39	1,609.07	227.30	.17
	Curry County:									
P46	Gold Beach	584.60	82.21	205.90	67.50	.54	5.33	524.30	529.70	.78
P86	Chetco	1,520.38	285.51		110.26		4.96	54.32	24.04	[a] .30

[a] No platinum.

[b] Includes ilmenite.

Proportion of various minerals in the black sands of the Pacific slope—Continued.

No. of sample.	Locality from which sample was obtained.	Magnetite.	Chromite.	Garnet.	Olivine.	Monazite.	Zircon.	Quartz.	Mixed minerals.	Gold and platinum.
	OREGON—continued.									
	Curry County—Continued.									
P87a	Port Orford	26.37	24.59	197.03	217.87			1,299.99	304.77	.30
P87b	Do	259.08	66.80	1,104.50	276.50	.07	2.99	289.84		.18
P88	Port Orford Beach	31.62	71.79	54.56	919.53		2.91	914.97		1.04
P97	Rogue River Beach	865.70	106.43	61.88	781.76		2.25	181.95		
P86		1,520.38	285.51		110.26		4.96	54.32	24.04	[a].30
	Jackson County:									
P13	Ashland	1,181.00	2.00	370.00		34.00	66.00	344.00		.15
P62	Gold Hill	183.20	1,691.00		[b]31.24		2.40	91.79		[a]82.68
P19	Jacksonville	1,463.00	[e]296.60	Trace.			4.14			74.00
P106	Medford	408.30	1,159.00					63.14	373.50	117.00
	Josephine County:									
P92	Holland	656.60	261.70	842.10	2.60		1.10	209.70	25.61	704.67
P34	Suttler Creek	1,146.00	[c]673.00				24.69	11.50		275.91
P67a	Waldo	27.37	8.75	73.98				1,890.00		25.73
P67d	Do	26.61	124.13	32.64			5.88	521.59	1,289.96	.25
P68a	Do	77.60	641.77	719.37			.45	223.00	337.40	[a]18.99
P68b	Do		22.34				28.00	371.44	1,596.00	[a].19
P95	Do	359.00	1,121.00				316.90	93.99	108.40	144.33
P18	Wolf Creek	392.60	90.60	690.20	31.70	.06	15.34	245.60	533.60	192.33
P73	Linn County: Foster	1,238.00	600.80	71.25		.10	.73	10.52		Trace.
	Multnomah County:									
P61a	Portland	10.95	50.78	15.43		.43	12.42	1,757.00		
P61b	Do	3.89	31.46					1,864.00		.11
P63a	Do	823.10	351.60	178.30	1.08	.59	133.10	429.50	82.17	15.86
P63c	Do	119.20	670.20	494.20	11.52	1.79	14.50	688.00	.40	17.78
P70	Polk County: Falls City	217.74	612.60	739.54	285.71	.35	101.96	40.59	1.68	.34
P37	Wallowa County: Wallowa	59.00	9.30	175.00		.67		630.50	[d]610.60	[a]2.25

[a] No platinum.
[b] Serpentine.
[c] Includes ilmenite.
[d] Pyrite.
[e] Includes hematite.

Proportion of various minerals in the black sands of the Pacific slope—Continued.

No. of sample.	Locality from which sample was obtained.	Magnetite.	Chromite.	Garnet.	Olivine.	Monazite.	Zircon.	Quartz.	Mixed minerals.	Gold and platinum.
	OREGON—continued.									
P28	Wasco County: Hood River Beach	995.00	[a]174.50	221.00	287.00	5.00	16.50			
P82b	Washington County: Hillsboro	[b]42.38						1,096.00	861.08	[c]3.40
P93	Umatilla County: Weston	981.10	688.00	113.30	36.89	46.63	122.40	12.03		204.34
	UTAH.									
	Salt Lake County:									
P72a	Salt Lake City	848.70	677.90	300.10		25.35	120.70	22.35		100.33
P72b	Do	1,532.00	321.80	78.45		1.97	43.76	16.39		[c]339.98
	WASHINGTON.									
	King County:									
P60	Seattle	10.82	.28	9.26		1.18	1.48	1,635.00		[c].31
P91	Do	1,779.00	17.23	128.00		16.33	.80	59.02		10.31
P83	Kittitas County	1,643.00	188.00	118.70				5.50	45.00	[c]315.00
	Whatcom County:									
P78	Bellingham	[b]1,978.60		2.57				18.26		Trace.
P79	Do	[d]1,427.00							[e]573.22	Trace.
P113	Do	[f]7.43		1.19	.96		.10	1,502.55	487.41	Trace.

[a] Includes ilmenite.
[b] Incudes hematite.
[c] No platinum.
[d] Limonite.
[e] Pyrite and iron phosphate or durfrenite.

In undertaking an examination of these specimens it was evidently necessary to define more or less generally what minerals should be considered "valuable." More than forty distinct mineral species were likely to be encountered in one or another of these sands, and of these there are very few which are not used industrially under some conditions in some part of the United States. The first essential condition determining the usefulness of any of the minerals is its purity. Therefore the ease with which the various minerals could be separated became an important feature to be determined by the investigation.

It was important to determine the most efficient means of separating the various minerals, as an aid in identifying them, in determining the proportion of each in a given sample, and, finally, in forming a satisfactory conclusion as to whether the conditions involved in separation would admit of classifying certain minerals as useful.

Prof. Robert H. Richards, dean of the mining school of the Massachusetts Institute of Technology, was promptly retained to carry out experiments in mineral separation, assisted by Mr. F. W. Horton. As many of the specimens received contained noteworthy quantities of gold and platinum, they were first assayed by Mr. Charles E. Locke, assistant to Professor Richards. These assays showed the following proportions of gold to platinum, where the latter element was detected:

Gold and platinum contained in black-sand concentrates from various placer-mining districts, by States and counties.

Number of sample.	State and county.	District.	Ounces per ton of concentrate.	
			Gold.	Platinum.
	ARIZONA.			
D 5007 No. 2	Yavapai	Columbia	0.79	0.06
D 5010	do	Granite Creek	Trace.	Trace.
D 5008	do	Walnut Grove	Trace.	Trace.
	CALIFORNIA.			
D	Butte	Oroville	19.94	27.45
D 8	do	Alvarado placer mine, Butte Creek	5.22	.17
D 26	do	Buchanan Hill	1.09	.08
D 29	do	Peavine Creek	7.03	.83
D 30	do	Empire	.08	Trace.
D 16	Calaveras	Wild Goose mine	39.08	.35
D 34	Humboldt	Orleans	19.00	4.00
D 9	Mendocino	Sec. 7, T. 16 N., R. 12 W	Trace.	Trace.
D 19	Nevada	Rough and Ready Township	5.60	.52
D 2	Placer	Taylor mine, North Fork American River, Colfax.	29.26	1.27
D 1	do	Southwest of Auburn	24.14	1.48
D 6	do	Gold Run	37.61	8.78
D 11	do	Gold Blossom mine, Butcher Ranch mining district.	191.60	3.36
D 23	do	American River	126.9	9.67
D 15	Plumas	Nelson Creek	1.45	.12
D 21	do	Bowlder Nest mine on Grizzly Creek, Genesee district.	1.44	.66
D 32	do	Rock Island Hill mine	10.80	.16
D 40	do	Little Grizzly mine	Trace.	Trace.
D 47 No. 1	do	La Porte	2.98	.21
D 38	San Bernardino	Van Dusan Canyon, Holcomb	.12	.06
D 5	Shasta	Sacramento River, North of Redding, Gem mine.	.64	.28
D 14	do	Gypsy mine, Shasta district	8.29	.25
D 18	Siskiyou	Fox Creek	.72	Trace.

Gold and platinum contained in black-sand concentrates from various placer-mining districts, by States and counties—Continued.

Number of sample.	State and county.	District.	Ounces per ton of concentrate.	
			Gold.	Platinum.
	CALIFORNIA—con.			
D 22	Siskiyou	Grouse Creek	10.31	0.18
D 36	do	Happy Camp district	None.	.82
D 20	Trinity	Junction City mining district	28.43	25.80
D 33	do	South Fork and Trinity River	9.02	1.28
D 35	do	T. 5 N., R. 7 E	4.90	4.61
	COLORADO.			
D 6037	Chaffee	Buena Vista	1.99	.43
D 6033	Costilla	San Luis Valley	None.	Trace.
D 6043	Pitkin	Junction of Gunnison, Chaffee, and Pitkin counties.	.05	.05
D 6029	Saguache	Pole Creek, Cretone	.34	.06
D 6006	San Miguel	West of Telluride	.37	.09
D 6016	do	Saw Pit	Trace.	Trace.
	IDAHO.			
D 4012	Bingham	West of Blackfoot	19.62	.18
D 4021	do	West bank Snake River	1.60	.70
D 4009	Boise	Oxbow tunnel. Payette River	.52	.28
D 4014	do	Gold Fork. North Payette River	2.02	.08
D 4010	Elmore	Bear Creek mining district, Rocky Bar	1.10	.11
D 4029	do	Baker Gulch, Crooked River	Trace.	Trace.
D 4017	Fremont	Gem Placer mine, Menan	Trace.	Trace.
D 4034	Idaho	Elk City district	1.06	.05
D 4023	Shoshone	Pierce City	.16	.04
D 4030	do	Big Island, North Fork Clearwater River	.16	.08
D 4031	do	Beaver Butte mining district, Trail Creek	6.40	Trace.
	MONTANA.			
D 1004	Granite	Princeton	1.67	.05
	NEW MEXICO.			
D 9006	Santa Fe	Los Cerrillos	Trace.	Trace.
D 9008	Lincoln	Tecolote Mountains	Trace.	Trace.
	OREGON.			
D 2002	Baker	South of Durkee	9.90	.22
D 2009, No. 1	Coos	Old Ocean Beach, Randolph mining district.	1.8	2.10
D 2009, No. 2	do	do	None.	.91
D 2009, No. 3	do	do	.02	.10
D 2045	do	Ocean Beach, Whiskey River	None.	.20
D 2010	do	Ocean Beach	1.25	6.23
D 2003	Douglas	East of Riddle	4.71	8.59
D 2006	do	Cow Creek mining district, Glendale	.50	2.25
D 2023	do	Riddle	19.27	128.73
D 2028	do	North Fork Steamboat River	.18	.02
D 2028, No. 2	do	Bohemian mining district	Trace.	Trace.
D 2014a	Josephine	Fry Gulch mine	1.88	4.53
D 2021	do	Galice Creek	None.	.26
D 2029	do	Sucker Creek	6.53	.67

Gold and platinum contained in black-sand concentrates from various placer-mining districts, by States and counties—Continued.

Number of sample.	State and county.	District.	Ounces per ton of concentrate.	
			Gold.	Platinum.
	OREGON—cont'd.			
D 2030	Josephine	Allen Gulch mine, Waldo	37.30	0.58
D 2013	do	Coyote Creek	None.	Trace.
D 2025	Linn	South Santiam River	2.60	3.52
D 2001	Union	Camp Carson district, Grande Ronde River	2.40	.12
	SOUTH DAKOTA.			
D 9504	Custer	French Creek	Trace.	Trace.
	UTAH.			
D 15516	Garfield	Colorado River	6.36	.15
D 15511	Morgan	North of Morgan	Trace.	Trace.

FIELD WORK.

Economy of time required that the examination of the conditions of occurrence of the heavy minerals in placer gravels should be undertaken long before the laboratory specimens had been completed. Therefore a corps directed at first by Prof. J. F. Kemp, of Columbia University, New York, proceeded to the well-known localities on the Pacific slope where previous examinations had shown the gravels to contain considerable percentages of minerals heavier than quartz.

Investigation of sands at the mouth of Columbia River.—On account of the accessibility and the slight cost of transporting the sands to the concentrating headquarters at Portland, an investigation was promptly undertaken of the seashore sands at the mouth of Columbia River. Mr. A. H. Gale, field assistant, visited Astoria and examined the coast sands from that point on the river beach to the mouth of the river at Fort Stevens and southward on the Pacific beach to Tillamook Head, a total distance of about 15 miles. The beach sands of this region are limited by a clay ridge extending from Tongue Point about 6 miles inland from the mouth of Columbia River southwest to the ocean beach at Tillamook Head. The triangle formed by this ridge and the ocean and river contains a great variety of sands which can be roughly grouped as follows:

Beginning at Tillamook Head the beach is made of heavy bowlders diminishing in size to the north until within less than a mile they change into heavy dark-green sands containing a small proportion of magnetite and other heavy minerals and a little quartz. Farther up the beach the sands are gradually lighter in color, with a much larger proportion of quartz, until the mouth of the river is reached. The jetty extending from Fort Stevens northwest to the deep channel has caused light-gray sands to fill in, building out the shore from the original beach about one-half mile and doubtless burying deposits of much heavier sand such as those immediately adjacent on the river beach. These sands on the south side of the mouth of the river are exceptionally black and contain a large proportion of magnetic iron ore and other heavy minerals. To the east from the ocean beach the usual sand dunes are encountered, consisting largely of quartz sand with very little magnetite or other heavy minerals. Still farther east, up to the clay ridge which limits the beach sands, the sands show an increasing percentage of clay, but only exceptionally carry any interesting proportion of heavy minerals. This region, bounded on the east by the clay ridge extending from Tongue Point to Tillamook Head, is known as Clatsop Plains.

Mr. Gale selected five carloads of the sand from this region, one of which represented the green sand on the beach in the neighborhood of Tillamook Head; another the heavy black sand on the river beach near Fort Stevens; a third represented the material directly east of the sand dunes and characteristic of the interior plain between the sand dunes and the clay ridge; a fourth was taken at Warrenton, also in the Clatsop Plains region toward the northeast; and the fifth was taken from the dredge *William H. Ladd*, which is excavating the river channel in Columbia River at Pillar Rock, about 12 miles from the mouth. In addition to these, many small samples were taken over this entire area wherever variations promised to give interesting results. Finally, by means of driving pipes to a depth of 100 feet, it was found that the surface conditions extended certainly that far, and well records at Hammond station show varying layers of sands and clay to a distance of 400 feet. The specimens were separated at the concentrating pavilion in Portland.

Examination was also made of the sands in the large sand bar of Columbia River opposite Hood River, Oregon. Twenty tons collected at this point were separated at the concentrating pavilion in Portland.

Field work in southern Oregon and in California.—After the investigation of the sands at the mouth of Columbia River, Mr. Gale joined Prof. J. F. Kemp at Grants Pass and aided him in the examination of the heavy sands found in the placer mines at Leland, Wolf Creek, Grants Pass, at the Champlin dredge south of Grants Pass, at Kirby, and at Waldo; proceeding southward they crossed the Oregon line at Crescent City, Cal., and turned north along the beach, collecting samples at Smith River, the mouth of Pistol River, the mouth of Rogue River, Gold Beach, Bandon, Marshfield, and Ophir, Oreg. Professor Kemp then examined similar placer deposits on Snake River in Idaho, while Mr. Gale turned to the south and examined the ocean beach from Crescent City to Eureka, Cal., and then went eastward to Weitchpec, on Trinity and Klamath rivers, California, and finally secured many valuable samples of black sands from Siskiyou, Sierra, and Butte counties, Cal.

Other beach sands were examined by Mr. W. T. Schaller at San Diego, Lompoc, Aptos, San Luis Obispo, and in the neighborhood of San Francisco, Cal.

Mr. H. E. Crain, of Cheyenne, Wyo., collected several tons of ore from the Rambler copper mine, Wyoming, for examination for platinum. He also visited the Bighorn Mountains of Wyoming and collected samples of black sands in that region.

Dr. Joseph Hyde Pratt investigated the placers of Yellowstone River near Miles City and Helena, Mont.

Mr. Walter Harvey Weed collected samples of chrome iron ore sand in the neighborhood of Soldiers Delight, Baltimore County, Md., and Mr. D. B. Sterrett collected a number of black-sand samples from the Balsam Forest region of North Carolina. Mr. F. C. Hess collected and shipped to Portland several tons of black sands from the beach at Cape Nome, Alaska. Mr. H. C. Landes, State geologist of Washington, and Mr. Earl W. Bachert collected several tons of black sands from the Pacific beach from Cape Flattery south to Ozette.

One of the writers collected a ton of black sand from Grays Harbor at Hoquiam, Wash.; another ton of sand, unusually rich in magnetite, from Damons Point, Grays Harbor; and several sacks of sand representing the Pacific beach at Moclips, Wash., as well as two carloads of tailings from the dredges at Oroville and Marysville, Cal.

CONCENTRATION EXPERIMENTS.

By the courtesy of the Lewis & Clarke Exposition Company, a pavilion, 100 feet long by 50 feet wide, adjoining the Mines Building on the exposition grounds was provided for the installation of concentrating machinery, thus enabling the Survey to carry on large-scale experiments to find the best methods of separating the useful minerals in the black sands collected. This concentrating plant was under the supervision of Prof. Robert H. Richards, of the Massachusetts Institute of Technology. The invitation to various manufacturers of concentrating machinery to cooperate in this work by sending full-sized machines resulted in the following equipment:

Wilfley concentrator, erected by the Mine and Smelter Supply Company, of Denver, Colo., and operated by Mr. A. W. Park.

Laboratory Wilfley concentrator, built for the United States Geological Survey.

Pinder concentrator, installed by the Joshua Hendy Machine Works, of San Francisco, and operated by the inventor, Capt. J. W. Pinder.

Woodbury concentrating table, installed and operated by the inventor, Mr. George E. Woodbury, of San Francisco, Cal.

Christensen concentrator, installed and operated by the inventor, Mr. C. Christensen, of Oretown, Oreg.

Wetherill magnetic separator, type E, full size, loaned by the Wetherill Magnetic Separator Company of New York. This machine has been arranged to be operated with a current varying from 0.015 ampere to 3.5 amperes. It was operated by Mr. Harmon V. Morse, of Johns Hopkins University, and by Mr. Hermann Gray.

Knowles magnetic separator, furnished by the American Contractor Company, of Joplin Mo., and operated by Mr. Thomas W. Johnson.

Three forms of hydraulic classifiers, devised by Prof. Robert H. Richards.

Amalgamating table, devised by Prof. Robert H. Richards.

Glass table with greased surface for the separation of special minerals after the South African diamond method.

Hendy Challenge ore feeder, loaned by the Joshua Hendy Machine Works.

Set of Imperial ore screens, loaned by Mr. John Traylor, of Denver, Colo., and operated by Mr. Clifford L. Gardiner.

Merrill ore muller, invented and operated by Mr. I. J. Merrill.

Laboratory rock crusher and laboratory ore pulverizer.

The capacity of this equipment is a carload of sand in eight hours. The plant is also provided with mechanical agitating apparatus for bottle amalgamation with sodium amalgam.

Assay laboratory.—An assay laboratory, 20 by 20 feet, has been established. Here the following apparatus, partly lent and partly purchased of the F. W. Braun Company, of San Francisco, Cal., and of Messrs. Eimer & Amend, of New York City, has been installed: No. 40 Braun's combination crucible and cupelling furnace, with complete blowpipe apparatus and Cary hydrocarbon burner; the necessary crucibles, cupels, scorifiers, fluxes, etc., and weighing devices, supplied by Eimer & Amend, including very fine pulp and button balances. The last-named firm has also supplied a small electric furnace and electric hot plate. All the necessary chemicals and apparatus for making simple mineralogic determinations are found here.

Method of treatment.—Obviously the course of treatment used has varied greatly with the kind of sand. These sands are grouped in two classes: (1) Sea sands, river sands, and sand-dune material; and (2) low-grade gravels, tailings from dredges and placer workings, and richer heavy tailings from the clean-up of dredges, etc.

The method of treatment of class 1 consists of sampling and feeding to a Hendy automatic feeder, from which it is elevated to the roof of the building, where the sand passes over the Traylor screen, with holes 1 mm. in diameter. The oversize is examined and the undersize is delivered to an automatic distributor which divides it evenly to the four tables through four iron pipes. Each of these machines separates the sands into three portions—concentrates, middlings, and tailings. All of the concentrates and middlings are collected, and samples of the tailings are taken every five minutes. Samples of these concentrates, middlings, and tailings are dried and then treated by the system devised by Mr. Henry E. Wood, of Denver, Colo., by which the sands are first separated on the Wetherill magnetic separator into six portions by five successively increasing strengths of current. The strengths of current used in this machine are such as to group together in separate portions (1) magnetite, (2) chromite and ilmenite, (3) garnet; (4) olivine, hypersthene, and similar heavy silicates; (5) monazite, and (6) a nonmagnetic residue containing zircon, quartz, iridium, iridosmium, gold, and some of the platinum.[a] These separations are the result of many experiments in regard to the magnetic permeability of these minerals, carried out on specimens obtained from mineral dealers in the East.

Each portion is then carefully examined by mineralogists, and where complete separation is not already effected the proportion of different minerals unseparated is ascertained as carefully as possible under the microscope.

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[a] Much of the crude platinum found, occasionally 60 per cent, is removable by a magnet.

In the examination for precious metals a separate kilogram sample of each product of the concentrating tables is mixed with water in a 2-gallon bottle. To this is added a small quantity of sodium amalgam, and after mechanical agitation for about thirty minutes it is found possible to extract practically all the free gold, platinum, and iridosmium, It has been found that the platinum and iridosmium will stick to the sodium amalgam as long as the sodium is not all converted by water into sodium hydroxide. As in some instances the gold has been found to be so coated with martite and other oxides of iron as to defeat amalgamation, each product is also examined by fire assay to determine the total gold and platinum.

In the treatment of class 2 the sands are sized through an 8-mm. screen. What remains on this screen is hand picked, and the screenings are passed over a 2-mm. screen. What remains on this screen is jigged for the separation of heavy minerals. The concentrates of the hand jig are hand picked. The material going through the 2-mm. screen is again sieved through a half-millimeter screen, and the coarse and fine materials are run separately after appropriate sampling on one of the tables. All the above concentrates are subjected to the same final examination as the sands of class 1.

Results.—The following table gives a synopsis of the results obtained by the concentration of various sands:

Results of concentration of black sands.

a. Lots in which a high per cent of the gold and platinum were concentrated into a small bulk.

Record number.	Locality from which sample was obtained.	Material.	Amount.	Actual value of gold and platinum in product.	
	OREGON.				
	Coos County:		*Pounds.*	*Dollars.*	*Per cent.*
P102a	Randolph district, beach	Concentrates	20	1.819	93.37
		Tailings, including No. 2 concentrates.	423.5	.129	6.63
P101	Whiskey Run, 7 miles north of Bandon.	Through 2 mm. on ½ mm.:			
		Concentrates Nos. 1 and 2.	1.497	.0022	73.11
		Tailings	22.5	.0008	26.83
	Josephine County:				
P68a	Waldo	Through ½ mm.:			
		Concentrates	19	2.015	87.87
		Tailings and No. 2 concentrates.	222.5	.277	12.11
P68a	Do	Through 2 mm. on ½ mm.:			
		Concentrates	37	.940	90.77
		Tailings and No. 2 concentrates.	393.5	.028	2.67
P67a	Do	Through 2 mm. on ½ mm.:			
		Concentrates No. 1	16.5	6.713	99.93
		Tailings	73.5	.004	.07
P67a	Do	Through ½ mm.:			
		Concentrates	11	.623	99.82
		Tailings	37.5	.001	.18

Results of concentration of black sands—Continued.

b. Lots in which a high per cent of gold and platinum was saved, but the concentrates are too large in quantity or there is some imperfection in the assays not yet located, or both.

Record number.	Locality from which sample was obtained.	Material.	Amount.	Actual value of gold and platinum in product.	
	CALIFORNIA.		*Pounds.*	*Dollars.*	*Per cent.*
P100b	Del Norte County: Smith River.	Concentrates Nos. 1 and 2	90	0.012	11.35
		Tailings	50	.000	.00
	OREGON.				
P102c	Coos County: Randolph district, beach.	Concentrates Nos. 1 and 2	165	.075	18.03
		Tailings, including No. 3 concentrates.	402	.026	6.29
	Curry County:				
P87b	Port Orford	Concentrates No. 1	18	.018	60.75
		Tailings, including No. 2 concentrates.	312	.000	.00
P88	Port Orford, beach	Concentrates Nos. 1 and 2	37	.033	40.61
		Tailings	121.25	.00	....

c. Lots in which the concentrates show values, while the original samples failed by assay to show any. The per cent can not be computed, therefore.

	ALASKA.				
P65	Cape Nome	Concentrates No. 1	147.25	0.047	....
		Tailings and No. 2 concentrates	1,941.75	(a)	....
	CALIFORNIA.				
P89b	Humboldt County: Gold Bluff.	Concentrates No. 1	24.5	.038	....
		Tailings, including No. 2 concentrates.	167	.000	....
	IDAHO.				
P113	Ada County: Boise	Concentrates No. 1	.25	.004	....
		Tailings, including No. 2 concentrates.	57.75	.000	....
	OREGON.				
P102d	Coos County: Randolph district, beach.	Concentrates No. 1	4.5	.013	....
		Tailings, including No. 2 concentrates.	123.5	.000	....
P97	Curry County: Rogue River, beach.	Concentrates No. 1	21	.003	....
		Tailings, including No. 2 concentrates.	44.5	.000	....
P70	Polk County: Falls City	Concentrates No. 1	9.5	.036	....
		Tailings	124.5	(a)	....

[a] Trace.

Results of concentration of black sands—Continued.

d. Lots in which the reduction of values in the tailings is complete, but the weight of the concentrates is much too large.

Record number.	Locality from which sample was obtained.	Material.	Amount.	Actual value of gold and platinum in product.	
	CALIFORNIA.		*Pounds.*	*Dollars.*	*Per cent.*
P99	Del Norte County: Crescent City.	Concentrates Nos. 1, 2, and 3	837	0.120	78.49
		Tailings	459	.0	.00
P89a	Humboldt County: Gold Bluff.	Concentrates No. 1	41.5	.647	99.17
		Tailings	175.5	.000	....
	OREGON.				
P102f	Coos County: Randolph district, beach.	Concentrates Nos. 1, 2, and 3	385	.142	98.27
		Tailings	171	.00	....
	Curry County:				
P46	Gold Beach	Concentrates Nos. 1 and 2	49	.041	99.81
		Tailings	58.25	.001	2.56
P86	Chetco	Concentrates Nos. 1 and 2	429.2	.050	73.09
		Tailings	36.8	.0004	.66
P67b	Josephine County	Concentrates Nos. 1 and 2	157.5	.153	100.80
		Tailings	565.5	.00	....

e. Lots in which the values are so minute that concentration has failed to reduce the values in the tailings and the assays fail to check up.

	CALIFORNIA.				
P89c	Humboldt County: Gold Bluff.	Concentrates Nos. 1 and 2	96.5	0.061	9.50
		Tailings	986	.291	45.25
	IDAHO.				
P105	Ada County: Boise	Concentrates Nos. 1 and 2	7	.017	15.04
		Tailings	289	.080	69.76
P81b	Bingham County: Quaker River.	Concentrates Nos. 1 and 2	3	.001	35.16
		Tailings	12	.002	75.25
	OREGON.				
P26	Baker County: Sumpter	Concentrates Nos. 1 and 2	5.5	.004	17.08
		Tailings	96.5	.018	83.32
P101	Coos County: Whiskey Run, 7 miles north of Bandon.	Through ½ mm.:			
		Concentrates Nos. 1 and 2.	1.93	.0008	39.07
		Tailings	23.07	.0013	60.77
P87a	Curry County: Port Orford	Concentrates Nos. 1 and 2	82	.026	31.46
		Tailings	476	.047	56.30

It is evident from the above results that a great majority of the black sands are sufficiently valuable to justify separation into their various mineral constituents by concentrating tables of the Wilfley, Pinder, Woodbury, and Christensen types; and it is evident also that the effective operation of these tables is comparatively independent of the fineness of the gold, since in many sands gold as fine as 200-mesh is readily saved on the tables—frequently from 95 to 98 per cent of the total assay value.

Further examination of black-sand localities and of concentrating methods during the remainder of the fiscal year 1906 has been recommended by the Secretary of the Interior.

SURVEY PUBLICATIONS ON TIN, QUICKSILVER, PLATINUM, TUNGSTEN, CHROMIUM, AND NICKEL.

The principal publications by the United States Geological Survey on the metals here grouped are the following:

Becker, G. F. Geology of the quicksilver deposits of the Pacific slope, with atlas. Monograph XIII. 486 pp. 1888.

——— Quicksilver ore deposits. In Mineral Resources U. S. for 1892, pp. 139–168. 1893.

Blake, W. P. Nickel; its ores, distribution, and metallurgy. In Mineral Resources U. S. for 1882 pp. 399–420. 1883.

——— Tin ores and deposits. In Mineral Resources U. S. for 1883–84, pp. 592–640. 1885.

Christy, S. B. Quicksilver reduction at New Almaden [Cal.]. In Mineral Resources U. S. for 1883–84, pp. 503–536. 1885.

Emmons, S. F. Platinum in copper ores in Wyoming. In Bulletin No. 213, pp. 94–97. 1903.

Glenn, W. Chromic iron. In Seventeenth Ann. Rept., pt. 3, pp. 261–273. 1896.

Graton, L. C. The Carolina tin belt. In Bulletin No. 260, pp. 188–195.

Hess, F. L., and **Graton, L. C.** The occurrence and distribution of tin. In Bulletin No. 260, pp. 161–187. 1905.

Hobbs, W. H. The old tungsten mine at Trumbull, Conn. In Twenty-second Ann. Rept., pt. 2 pp. 7-22. 1902.

——— Tungsten mining at Trumbull, Conn. In Bulletin No. 213, p. 98. 1903.

Kemp, J. F. Geological relations and distribution of platinum and associated metals. Bulletin No. 193. 95 pp. 1902.

Packard, R. L. Genesis of nickel ores. In Mineral Resources U. S. for 1892, pp. 170–177. 1893.

Rolker, C. M. The production of tin in various parts of the world. In Sixteenth Ann. Rept., pt. 3, pp. 458–538. 1895.

Ulke, T. Occurrence of tin ore in North Carolina and Virginia. In Mineral Resources U. S. for 1893, pp. 178–182. 1894.

Weed, W. H. The El Paso tin deposits [Texas]. Bulletin No. 178. 6 pp. 1901.

——— Tin deposits at El Paso, Tex. In Bulletin No. 213, pp. 99–102. 1903.

Weeks, F. B. An occurrence of tungsten ore in eastern Nevada. In Twenty-first Ann. Rept., pt. 6, pp. 319–320. 1901.

——— Tungsten ore in eastern Nevada. In Bulletin No. 213, p. 103. 1903.

LEAD AND ZINC.

A NEVADA ZINC DEPOSIT.

By H. Foster Bain.

Introduction.—The production of zinc ores in the Western States has begun to assume great importance. In 1905 the number of producing camps and the total shipments were much larger than in 1904. Colorado, with Leadville as the main shipping district, continued in the lead. The mines of the Magdalena Mountains in New Mexico made heavy shipments. Utah, Idaho, and Montana have become important producers, and smaller shipments have been made from other States and Territories, including Nevada. Important amounts of ore have been brought in from Mexico and some from British Columbia. Old mines are being reopened, new mills are being built, and everywhere through the West the zinc-ore industry is attracting large attention. In the summer of 1905 the writer visited the main zinc-producing districts of the West, and a general report on the western zinc industry is now in preparation as a joint publication of the division of geology and the division of mineral resources. In the course of this investigation the Potosi mine in southern Nevada was visited, and certain of its geologic relations were found to be so interesting that this brief separate discussion has been prepared.

The Potosi mine is located on the western slope of Spring Mountains, about latitude 36° N., longitude 115° 30′ W. It is reached by a 30-mile drive from Good Springs station on the San Pedro, Los Angeles and Salt Lake Railway. The springs from which the station takes its name are about 7 miles west of the railway, at the eastern foot of the mountains, and mark a well-known resting and camping place. The mine proper is near the old Mormon trail from Salt Lake City to Los Angeles and was first worked nearly half a century ago to furnish lead bullets for the pioneers. It had been idle for many years when the coming of the railway and the demand for zinc led to its reopening.

The mountains have been visited by J. R. N. Owen, Gilbert, Weeks, Rowe, and Spurr. The latter has summarized existing knowledge regarding them as follows:[a]

> The Spring Mountain Range is an exceedingly irregular-shaped group of mountains, lying southwest of Las Vegas Range, and separated from the Kingston Range, farther south, by the Pahrump Valley. The general trend of the range is northwest and southeast, and its length in this direction is about 60 miles, and at its northern end, in the neighborhood of Charleston Peak, the total width is as much as 30 miles. This peak constitutes the highest portion of the range, being 10,874 feet above the sea, and is a conspicuous landmark. This range is divided into numerous ridges, which run in many different directions without much visible system. At at least two points at the northern base of the range there occur warm springs, namely, Indian Spring and the spring at White's ranch in Pahrump Valley. This is interesting, since the range contains few igneous rocks.

Geology.—The rocks forming the mountains consist of Cambrian, Carboniferous, and Jurassic sediments, and, near Good Springs proper, a small area of basalt with at least one acidic porphyry rock. The Cambrian rocks are found in the northern part of the range and include a blue-gray crystalline limestone, greenish-yellow shales, and thin bands of dark sandstone. A quartzite associated with the limestone is probably also of Cambrian age. The Carboniferous rocks include Mississippian and Pennsylvanian limestones and a considerable thickness of red shale and sandstones. The Mesozoic rocks are represented by conglomerates, sandstones, and shales and carry Jurassic fossils.

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[a] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: Bull. U. S. Geol. Survey No. 208, 1903, p. 164.

Structurally the range is somewhat peculiar, being apparently anticlinal in a north-south section and showing a wrinkled synclinorium in an east-west section. The main mass of the mountains consists of Carboniferous limestones. The Cambrian rocks have been brought up and the Mesozoic let down, with reference to the Carboniferous, by heavy thrust faulting.

No very careful or detailed study of these or any of the surrounding mountains has yet been made and very little is really known of the geology. In the present instance no attempt was made to study the geology of the district, attention being concentrated upon the ore body and the mine.

Ore deposit.—The Potosi mine is located near the mountain marked Olcott Peak on Spurr's map. The limestone here is predominantly fine grained, breaking with a clean conchoidal fracture and being usually dark colored and occasionally very bituminous. Certain of the beds are cherty, but the chert is unequally distributed, much of the limestone being apparently free from it. The beds in which the ore occurs are not cherty. Fossils occur rather abundantly, though none were found immediately in connection with the ore bodies. The forms collected were examined by G. H. Girty and found to be common Carboniferous species, such as especially characterize the "blue limestone" at Leadville. The rocks have been folded sharply and faulted. The ore is found in certain little-disturbed and nearly horizontal beds having a slight dip to the east. The adits by which the mine is opened are in a perpendicular cliff facing west, at the head of a deep arroyo. This cliff seems to mark a fault scarp revealed by erosion. The fault plane, which is apparently vertical and runs approximately north and south, separates the little-disturbed beds on the east from the crumpled and folded limestones which form spurs on either side of the arroyo and stretch off to the west.

The adits, of which there are two, are about 800 feet above the plain, or at an altitude of approximately 6,500 feet. Above these the hill rises first abruptly and then more gently at least 300 feet. The main ore-bearing bed is flat lying, is about 5 feet thick, and lies immediately above a body of thin-bedded shaly limestone about 20 feet thick. This shaly limestone is dark colored, fine grained, and hard. It is made up of individual beds about 2 inches thick separated by clay partings one-fourth to one-half inch thick.

At right angles to the cliff—that is, running east—the limestone is cut by a series of narrow crevices, in the main pitching south. These show no faulting and are better developed in the limestone above the shaly bed than in it or below. A prospect drift, however, run in a hundred feet or so at the base of the shaly limestone follows one of these crevices. Similar crevices showing some mineralization are said to be traceable as much as 1,000 feet along their strike, though offsetting cross faults occur. There was not time to verify these statements.

The ore consists mainly of carbonate of zinc. Carbonate of lead, some sulphate, and galena also occur. There are occasional copper stains. No pyrites was seen, but iron oxide stains are common. The mine is dry and oxidation has gone far. The galena is only slightly argentiferous. A random sample examined in the Survey laboratory by George Steiger showed practically no silver present. It is said that some ore shipments have run as high as 12 ounces in silver to the ton, but ordinarily neither gold nor silver is determined. The main shipments are zinc carbonate running 40 to 45 per cent of zinc. A mixed grade running 35 per cent of zinc and 20 per cent of lead is also occasionally sold. There is no known gold value.

In general appearance and in mode of occurrence the ore bodies are curiously like some which have been worked in the upper Mississippi Valley region. The long-pitching crevices which show no faulting are similar to the well-known "pitches" of that district, while the concentration or "making" of the ore along the top of the shaly limestone is equally like the relations of the Wisconsin ore to the "oil rock." In Nevada the long period of desert conditions has caused the minerals, which in Wisconsin are generally sulphides, to be largely altered to carbonates and oxides. Similar ores are found in Wisconsin, but generally at levels considerably above the "oil rock," both stratigraphically and topographically. In both cases the ore constitutes a run as defined by Prof. W. P. Jenney[a] along the intersection of a crevice and a favorable horizon; here it is rather just above an unfavorable or impervious stratum. The ore bodies are exceedingly irregular in detail, following the minor fractures and ramifying watercourses through the limestone. In the Potosi mine small druses an inch or so in diameter were noted, which were lined with zinc carbonate, though apparently not connected with any regular crack. Chimneys of ore run up irregularly along the crevices, but so far no ore shoots running down through the shale have been found.

Origin.—The mode of occurrence favors the notion of a simple downward circulation of ore-bearing waters arrested by a nearly impervious bed and depositing their load of mineral along its top. If the original deposition was in the form of sulphides, as is quite probable, the organic matter of the shaly beds was probably important. The subsequent period of oxidation has, however, been so long as to obscure the records of any early stages in this ore body. If we look back to an earlier period, when rainfall was more abundant in this area, we can readily conceive of the formation of these ore bodies under present structural and topographic conditions without any demand on additional agencies. Indeed, it is even possible that in the winter and rainy months the ore is now being concentrated by a simple downward circulation of meteoric waters.

Whether such a simple hypothesis be in fact the correct one in this case can not be determined without more detailed study. For the present it is sufficient to show that it is a perfectly possible explanation of the known facts. Near the mine, as has been noted, is an important fault plane which presumably might have afforded openings for a deep circulation, though the course of the ore body is well developed at right angles to this plane. Warm springs, as noted by Spurr,[b] occur in the mountains but not near the ore bodies, nor are ores known to occur near the springs. One spring, a cold one, is found not far from the mine. No igneous rocks are known nearer than a dozen miles or more from the mine, though in the part of the mountains in which they are found there are certain lead and copper deposits not visited. Prof. E. M. Jenney[c] describes the lead deposits as similar in character and form to those of Missouri, and sees in this similarity an additional reason for referring the Missouri deposits to deep-seated waters connected genetically with some unknown igneous rocks. To the writer it would seem that the analogy might quite as well be the other way and that the relation to igneous rocks in the Spring Mountains was accidental rather than causal.

It has been customary in discussions of Western ore deposits to assign to igneous rocks an important genetic rôle. This has been done for deposits essentially valuable for the lead, zinc, or copper content, as well as for those in which gold and silver formed the main element of value. The general validity of the reasoning as applied to the precious-metal deposits is not here questioned, but it seems to the writer that a question may well be raised with regard to those deposits which are mainly valuable for lead and zinc or in which the gold and silver values are small. It is well known that in the Mississippi Valley there are important deposits of lead and zinc ores found in limestone and dolomites and considered by most investigators to have no direct genetic relations to igneous rocks. These ore bodies are characterized by a very simple association of minerals. They are free from arsenic, antimony, and the rarer complex sulphides, and are low in silver where not wholly nonargentiferous. Their origin can not be assigned to igneous rocks, since there are no such rocks to which to relate them and adequate alternative hypotheses are available.

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[a] Jenney, W. P. Lead and zinc deposits of the Mississippi Valley: Trans. Am. Inst. Min. Eng., vol. 22, p. 189.

[b] Op. cit., p. 165.

[c] Personal communication.

In the West there are considerable bodies of similar lead and zinc ores also found in limestones, and low in silver or free from it. If the explanation advanced for the Mississippi Valley ores be adequate it may well be asked why a more complex origin need be assumed for these ore bodies in the West. In a majority of cases in the West it is true that gold, silver, arsenic, antimony, and other metals characteristic of the ore bodies held to originate in part, at least, through igneous agencies, occur with the lead and zinc, as at Leadville, Park City, Aspen, and elsewhere. It may still be asked why it can not be believed that disseminated lead and zinc in the limestone contributed in an important degree to the ore bodies. Emmons, after an elaborate investigation of the country rocks at Leadville, reached the cautious conclusion that, "although the above facts are not sufficiently conclusive to afford absolute proof that the metallic contents of the deposits were entirely derived from the eruptive rocks, they certainly show the possibility and even probability that this source furnished a part at least of the vein metals."[a] It has been common in subsequent discussions to consider the porphyry rather than the sedimentary rocks as the original home of the metallic minerals, and to follow Emmons[b] in his conclusion that the association of the ores with the limestone is due to the chemical and physical characteristics of the rock—characters which are believed to have given it a selective affinity for ore solutions penetrating the formations as a whole.

At Aspen there are similar limestones and dolomites associated with igneous rocks, but Spurr[c] suggested only the igneous rocks as the original source of the metals. To the writer it would seem more probable that both igneous and sedimentary rocks have contributed their quota to the ore bodies.

The "blue limestone" of Leadville is a well-known metalliferous horizon through several Western States. As noted in the description above, it is in this limestone that the Potosi ores occur. The zinc ores of the Magdalena Mountains in New Mexico apparently come from the same horizon, and in fact the formation is quite as closely associated with lead and zinc in the West as are the Cambro-Silurian rocks of the Mississippi Valley and Appalachian regions. Emmons, in his investigations of the Leadville deposits, considered the hypothesis that the association was primary, but concluded that the exceptions were too numerous to warrant its adoption. He cited in particular the fact that in the adjacent Ten Mile district the ores were in the upper rather than the lower Carboniferous. As noted, he appealed to the physical and chemical nature of the limestone to account for the localization of the ores. It is true, however, that limestones and dolomites of widely differing characteristics serve as country rock to deposits, but that all or nearly all of them are indicative of base-level conditions on the land at the time of their formation—conditions under which chemical denudation and transportation are disproportionately important. Under such conditions the leaching of preexisting rocks is a most important process, and ore minerals, as well as others, may easily be carried to the sea in relative abundance. It would seem that conditions in the sea, if limestones be formed or forming, should be as favorable to the deposition of the ore minerals as at any later period in which similar solutions may be brought into contact with the limestone. The very chemical and physical characteristics appealed to may well be supposed to be operative in the early as well as the later period, and so the limestones as laid down should be storehouses of disseminated ore minerals. These general and theoretical considerations, coupled with the present distribution of the ores, warrant, it is believed, the suggestion that in the Rocky Mountain and Great Basin regions, as in the Mississippi Valley, paleogeography was not without its influence in localizing the ore districts. It is not intended to suggest that this is a complete explanation of the ore bodies of these districts, but merely to urge its consideration as one factor in a very complex process.

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[a] Geology and mining industry of Leadville: Mon. U. S. Geol. Survey, vol. 12, 1886, p. 582.
[b] Op. cit., pp. 540 et seq.
[c] Geology of the Aspen mining district, Colorado: Mon. U. S. Geol. Survey, vol. 31, 1898, p. 235.

SURVEY PUBLICATIONS ON LEAD AND ZINC.

Many papers relating to silver-lead deposits will be found included in the list on pages 9 to 13 of this bulletin. The principal other papers on lead and zinc, published by the United States Geological Survey, or by members of its staff, are the following:

Adams, G. I. Zinc and lead deposits of northern Arkansas. In Bulletin No. 213, pp. 187–196. 1903.

Adams, G. I., and others. Zinc and lead deposits of northern Arkansas. Professional Paper No. 24, 118 pp. 1904.

Bain, H. F. Lead and zinc deposits of Illinois. In Bulletin No. 225, pp. 202–207. 1904.

——— Lead and zinc resources of the United States. In Bulletin No. 260, pp. 251–273. 1905.

Bain, H. F., Van Hise, C. R., and Adams, G. I. Preliminary report on the lead and zinc deposits of the Ozark region (Mo.-Ark.). In Twenty-second Ann. Rept., pt. 2, pp. 23–228. 1902.

Clerc, F. L. The mining and metallurgy of lead and zinc in the United States. In Mineral Resources U. S. for 1882, pp. 358–386. 1883.

Ellis, E. E. Zinc and lead mines near Dodgeville, Wis. In Bulletin No. 260, pp. 311–315. 1905.

Grant, U. S. Zinc and lead deposits of southwestern Wisconsin. In Bulletin No. 260, pp. 304–310. 1905.

Hoffman, H. O Recent improvements in desilverizing lead in the United States. In Mineral Resources U. S. for 1883–84, pp. 462–473. 1885.

Iles, M. W. Lead slags. In Mineral Resources U. S. for 1883–84, pp. 440–462. 1885.

Keith, A. Recent zinc mining in East Tennessee. In Bulletin No. 225, pp. 208–213. 1904.

Ransome, F. L Ore deposits of the Cœur d'Alene district, Idaho. In Bulletin No. 260, pp. 274–303. 1905.

Smith, W. S. T. Lead and zinc deposits of the Joplin district, Missouri-Kansas. In Bulletin No. 213, pp. 197–204. 1903.

Ulrich, E. O., and Smith, W. S. T. Lead, zinc, and fluorspar deposits of western Kentucky. In Bulletin No. 213, pp. 205–213. 1903. Professional Paper No. 36, 218 pp. 1905.

Van Hise, C. R. Some principles controlling deposition of ores. The association of lead, zinc, and iron compounds. Trans. Am. Inst. Min. Eng., vol. 30, pp. 102–109, 141–150.

Van Hise, C. R., and Bain, H. F. Lead and zinc deposits of the Mississippi Valley, U. S. A. Trans. Inst. Min. Eng. (England), vol. 23, pp. 376–434.

Winslow, A. The disseminated lead ores of southeastern Missouri. Bulletin No. 132, 31 pp. 1896.

Wolff, J. E. Zinc and manganese deposits of Franklin Furnace, N. J. In Bulletin No. 213, pp. 214–217. 1903.

ALUMINUM.

The known bauxite districts of the United States were examined and reported on in detail some years ago by Dr. C. W. Hayes, and so far no large extension of the industry has taken place outside the area covered by his work. That such an extension is possible, however, is evidenced by discoveries which have been made during the past two years. Bauxite deposits of more or less promise have been uncovered in the vicinity of Fort Payne, Ala., as well as in Tennessee, Virginia, and Pennsylvania. In all these cases the bauxite is associated with Cambrian or Cambro-Ordovician rocks—the Knox or Shenandoah limestone of the valley regions—so that the newly found ore bodies correspond clearly to the type described by Hayes from Alabama and Georgia.

SURVEY PUBLICATIONS ON ALUMINUM ORES—BAUXITE, CRYOLITE, ETC.

The following reports published by the Survey contain data on the occurrence of aluminum ores and on the metallurgy and uses of aluminum:

CANBY, H. S. The cryolite of Greenland. Nineteenth Ann. Rept., pt. 6, pp. 615-617. 1898.

HAYES, C. W. Bauxite. In Mineral Resources U. S. for 1893, pp. 159-167. 1894.

——— The geological relations of the southern Appalachian bauxite deposits. Trans. Am. Inst. Min. Eng., vol. 24, pp. 243-254. 1895.

——— Bauxite. Sixteenth Ann. Rept., pt. 3, pp. 547-597. 1895.

——— The Arkansas bauxite deposits. Twenty-first Ann. Rept., pt. 3, pp. 435-472. 1901.

SCHNATTERBECK, C. C. Aluminum and bauxite (in 1904). In Mineral Resources U. S. for 1904, pp. 285-294. 1905.

STRUTHERS, J. Aluminum and bauxite (in 1903). In Mineral Resources U. S. for 1903, pp. 265-280. 1904.

IRON AND MANGANESE.

During the past year special attention has been attracted to the American iron industry, both by its remarkably prosperous condition and also by the publicity which has been given to attempts to effect a merger of important southern iron interests. Another feature worthy of note has been the commencement of active exploration work on western iron deposits. In both these fields the Survey has taken up detailed work during 1905, and preliminary reports on the results of some of this work are presented in the following papers:

THE CLINTON OR RED ORES OF NORTHERN ALABAMA.

By Edwin C. Eckel.

Introduction.—During the fall of 1905 detailed work was commenced on the iron ores of Alabama. The Clinton or red ores were examined in the district along the flanks of Lookout Mountain, from the Georgia line to Attalla and Gadsden; and the brown ores of the Anniston and Talladega districts were also surveyed. The present preliminary report contains notes on the developments in the red-ore districts covered.

In view of the practical importance of the subjects, descriptions of the ores of this district will be prefaced by brief notes on the origin and character of the red ores in general.

ORIGIN AND CHARACTER OF THE CLINTON ORES.

THEORIES OF ORIGIN.

For many years the origin of the oolitic and fossil ores which occur in rocks of "Clinton" age has been a much discussed subject. Minor points of difference being disregarded, it may be said that the various theories which have been advanced to account for the origin of these ores can be reduced to two. These two opposing theories are, briefly stated, as follows:

(1) *Original deposition.*—The ores were formed at the same time as the rocks which inclose them, having been deposited in a sea or basin along with the sandstones and shales which now accompany them.

(2) *Replacement.*—The ores are of much later origin than their inclosing rocks, having been formed by the replacement of original beds of limestone by iron brought in by percolating waters.

PRACTICAL IMPORTANCE OF THE QUESTION.

In addition to the questions of purely geologic interest which are connected with the differences of opinion as to the origin of the Clinton ores, the matter has a very distinct practical bearing on the working of the ores. This phase of the subject may be stated as follows:

If the ore deposits are due to the replacement of a limestone we can expect them to rapidly decrease in value with depth, becoming lower in iron and higher in lime, until at no great depth the bed will consist entirely of unaltered limestone.

If, on the contrary, the ore deposits are original, no such regular decrease in richness is to be expected as the mines are driven deeper. Patches of low-grade ore may be struck, but these will be due to original differences in the richness of the ore, and a slope might pass downward through such a patch of lean ore into another zone of high-grade ore.

PROBABLE METHOD OF ORIGIN.

In the present report no attempt will be made to discuss the arguments that have been advanced on both sides of this question, though such a discussion will be given in the final report on the district. For this paper, however, it will be sufficient to say that in the writer's opinion the ores unquestionably originated at the same time as their inclosing sediments, and that, except immediately at the surface, they have been subjected to no later alterations or enrichments. As pointed out above, this theory of origin implies that the ore bodies are practically continuous in depth and that they could be followed down the dip, in a syncline or basin, until the dips changed and the workings reached the surface on the other side of the fold. The practical importance of this is obvious, for it implies that the ore bodies can be traced and measured as exactly as if they were coal seams or limestone beds. The amount of Clinton ore in any area can probably be determined by a geologist within 5 or 10 per cent, and estimates of red-ore reserves can be made by competent men with a degree of accuracy impossible in dealing with the magnetite, hematite or brown ores of other districts.

"HARD" AND "SOFT" ORES.

The terms "hard" and "soft," as applied to the two principal varieties of Clinton ores, are hardly expressive of the facts, for the distinction between the two varieties in question is based on differences in their chemical composition rather than on differences in hardness.

The red ore of Alabama is, in its typical or "hard" variety, a highly limey ore. The ore beds are usually underlain by comparatively impervious shales and in most places dip at fairly high angles. These conditions favor the penetration of the ore, near the surface, at least, by percolating water. The result is that near the outcrop and for some distance down the slope the lime carbonate of the original ore is largely or entirely leached out. This removal of one constituent of course increases the relative percentages of the remaining less soluble constituents, while it renders the ore more porous and friable. The resulting "soft ore" is therefore very low in lime and correspondingly high in iron oxide. A secondary effect of the change, shown best when the cover is heavy and the dip low, is that the overlying shales settle down slightly as the bulk of the ore is reduced, so that on the outcrops the ore bed often appears to be less than its true underground thickness.

RED ORES OF NORTHERN ALABAMA.

GEOLOGY OF THE DISTRICT.

The geologic section found in this district is as follows, from above downward:

Geologic section in northern Alabama.

Formation.	Age.	Thickness.
		Feet.
Bangor limestone	Carboniferous	500-800
Fort Payne chert		100-250
Chattanooga shale	Devonian	20-30
Rockwood ("Clinton") shale	Silurian	400-800
Chickamauga ("Trenton") limestone		600-1,800
Knox limestone	Ordovician	2,000-4,000

Along the western side of Lookout Mountain, in Little Wills Valley, the rocks dip at low angles (10° to 30°) toward the mountain; on the eastern side the rocks dip steeply toward the mountain and are often almost vertical. The crest of Lookout Mountain is composed of the Coal Measures, and the Bangor limestone outcrops on the flanks of the mountain and underlies Little Wills Valley. The ridge northwest of this valley—the "Red Mountain"—shows the Fort Payne chert along its southeastern face, while the Rockwood beds, including the ore seams, form its crest and northwestern flank.

ORE DEVELOPMENTS OF THE DISTRICT.

The Clinton ores have been carefully traced throughout this district by Dr. C. W. Hayes and the writer, and in the final report large-scale maps will be included, showing the exact location of the ore-bearing formation. Since such maps can not be presented here, attention will be confined to a description of the developed ore deposits of the region. These will be described in geographical order, from Battelle south to Attalla, after which the chief facts concerning the Gadsden and Gaylesville deposits will be briefly noted.

Battelle.—The mines of the Ragon Mining Company, which supply the furnace of the Lookout Mountain Iron Company at Battelle, are located about one-fourth mile west of the furnace, on the northwest side of Red Mountain. Four ore beds are shown in the section here, with following dips and thicknesses and approximate distances apart:

Section showing ore beds near Battelle, Ala.

	Dip (south-east).	Thick-ness.
	°	*Feet.*
Bed 1 (top)	23-45	4½
Shale		40
Bed 2	25-45	2
Shales		300
Bed 3	85	3
Shales		200
Bed 4	85	3⅓

Of these beds, however, the second is too sandy to be workable and the third seems to be a very local development which can not be traced many feet from its outcrop. The first or top bed is worked by three slopes, each of which is now down about 200 feet; the fourth bed has two small and almost vertical openings.

The soft ore has been practically worked out, and the mines are now entirely in a hard, very limy ore. The following analyses, by Mr. I. P. Todd, chemist of the Lookout Mountain Iron Company, will serve to show the range in composition of the ore from the different beds and slopes:

Analyses of ores from mines near Battelle, Ala.

	Silica (SiO_2) and alumina (Al_2O_3).	Metallic iron (Fe).	Lime (CaO).	Magnesia (MgO).
Upper bed, slope 1	11.80	27.50	22.08	2.50
	9.40	29.30	22.87	n. d.
	10.60	29.40	22.40	n. d.
Upper bed, slope 2	7.20	31.18	22.54	n. d.
	8.40	31.30	23.04	n. d.
Upper bed, slope 3	15.60	24.15	23.45	n. d.
	12.60	24.80	24.20	n. d.
	12.90	23.25	26.05	n. d.
	15.00	25.30	22.90	n. d.
Bottom bed, slope 4	9.80	32.57	20.04	n. d.
Bottom bed, slope 5	10.10	31.77	20.54	n. d.

The difference in the ore from the different slopes on the upper bed is rather marked, for slope 2 averages 31.24 per cent of metallic iron, while slopes 1 and 3 average only about 27 per cent. This is accounted for by the fact that the ore from slopes 1 and 3 passes through a crusher, while that from slope 2 is hand picked and sledged over bars. The ore from the bottom bed, as will be seen, is somewhat better than even the best ore from the upper bed.

Mr. Todd furnished the following average analysis of all the hard ore, as fed to the furnace:

Average analysis of hard ore from mines near Battelle, Ala.

Silica (SiO_2)	9.20
Alumina (Al_2O_3)	3.68
Metallic iron (Fe)	27.00
Manganese (Mn)	.13
Lime (CaO)	22.54
Magnesia (MgO)	1.22
Phosphorus (P)	.376

Fort Payne.—McCalley[a] quotes the section shown by a well driven at Fort Payne furnace, probably about 1890. Rearranged slightly, this section is as follows:

Section of well at Fort Payne furnace, Alabama.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	25	0–25
Fort Payne chert	190	25–215
Devonian black shale	12	215–227
"Clinton" green and gray shales	340	227–567
"Clinton" shales and ore	18	567–585
"Clinton" shales, sands, and ore	50	585–635
"Clinton" shales and sandstone	180	635–815
"Clinton" ferruginous sandstone	50	815–865
"Clinton" shales and sandstone	40	865–905
Chickamauga limestone		905–

The well section given above can be compared directly with the following section, measured in 1905 by Mr. L. N. Christensen and the writer through the gap back of Fort Payne furnace.

Section through gap back of Fort Payne furnace, Alabama.

	Feet.
Fort Payne chert.	
Chattanooga shale	24½
Sandstone and shale	306
Ore	2–2½
Shale parting	1½–2½
Ore	2½–3
Shale	270
Covered interval, probably mostly limestone	246
Chickamauga limestone.	

Readings taken at a number of points in this gap gave a very uniform dip—varying only from 13½° to 15° to the southeast.

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[a] Report on the Valley Regions of Alabama, pt. 2, p. 154.

The mines formerly worked to supply the Fort Payne furnace are located about half a mile northwest of the furnace, in the gap above mentioned. The original report on this property gave the following analyses for the ore from the mines:

Analyses of ores from mines near Fort Payne, Ala.

	Soft ore.	Hard ore.
Silica (SiO_2)	10.37	4.11
Metallic iron (Fe)	55.34	25.39
Lime (CaO)	1.07	30.13
Phosphorus (P)	.46	.34

While these analyses are quoted from a prospectus and the name of the analyst is unknown, the analysis of the hard ore at least seems to contain internal evidence as to its accuracy, for no prospectus writer would imagine a 25 per cent ore.

Analyses by J. L. Beeson [a] of samples from old surface cuts near the Fort Payne mines gave the following results:

Analyses of ore from surface cuts near Fort Payne, Ala.

	Soft ore.	Hard ore.
Silica (SiO_2)	7.93	3.97
Metallic iron (Fe)	56.02	26.41
Lime (CaO)	n. d.	29.80
Phosphoric anhydride (P_2O')	.52	.86

It will be seen that these check closely with the reported analyses of the Fort Payne furnace ores.

Portersville.—The Portersville mines of the Southern Steel Company are located about three-fourths of a mile northwest of Portersville station, near the northwestern flank of Red Mountain. A switch track from the mines to the Alabama Great Southern Railroad passes on a very easy grade through a convenient gap in the red ridge.

The principal openings at present are on the north side of this gap, though extensive stripping is now in progress on the south. The main slope shows a section about as follows:

Section in main slope of mine near Portersville, Ala.

	Inches.
Shales.	
Ore	24
Shale	12-18
Ore	24

This slope is now down 400 feet on the dip of the ore, which is 15° SE.; and below cover the ore beds thicken slightly in places to give a total thickness of 4½ feet. Owing to the heavy shale parting between the seams the stripped ore is hardly as clean as that of the Crudup mines.

On the south side of the gap 5 to 30 feet of stripping (soft greenish shale) is being removed so as to get back to a point where the roof is firm enough to permit underground mining.

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[a] McCalley, Report on the Valley Regions of Alabama, pt. 2, p. 153.

Measurements of the ore here gave the following results:

Sections on south side of gap near Portersville, Ala.

	1.	2.
	Inches.	*Inches.*
Ore	20	23
Shale	14	8
Ore	17	20

About 50 feet vertically below this main ore bed a thin seam of ore, perhaps averaging 1 foot in thickness, shows in the road. This is not worked, and no other ore seams have been found.

The following analyses by M. C. Shannon cover the results on a large number of carloads of the Portersville hard ore:

Analyses of Portersville hard ore.

	1.	2.	3.	4.	5.	6.	7.	8.	Average.
Silica (SiO_2) Alumina (Al_2O_3)	5.56	4.94	5.60	9.18	6.42	7.86	5.80	5.02	6.29
Metallic iron (Fe)	33.05	33.72	25.52	38.00	30.35	31.20	31.95	32.00	31.98
Lime (CaO)	25.20	22.90	30.82	19.04	25.88	23.71	26.62	24.22	24.80
Phosphorus (P)	n. d.	n. d.	n. d.	n. d.	n. d.	n. d.	n. d.	n. d.	....

Crudup.—The Lacey-Buck Iron Company operates mines on an exceptionally heavy ore bed at Crudup, the ore being mostly shipped to the furnaces at Trussville, Ala. The ore bed is from 5 to 7 feet thick, without any shale parting. At the mine the bed dips 26° SE. The mines were formerly worked as open cuts, but now practically all the ore comes from a single slope. No analyses of ore from these mines are at present available, but McCalley quotes the following as an average of the ore from a group of old workings near Crudup:

Average analysis of ore from old workings near Crudup, Ala.

Silica	10.51
Metallic iron	42.45
Phosphorus anhydride	1.017

Attalla.—In the immediate vicinity of Attalla two mining companies are now operating on the red ore, the mines being located west and northwest of the town, on and near Moragne Mountain.

The mines of the Alabama Consolidated Coal and Iron Company are located near a gap at the northeast end of Moragne Mountain, about half a mile north of Attalla. The ore here is from 3 to 4 feet thick, dips 30° to 35°, and has been worked down on the slope for almost a thousand feet without marked change in character. This fact is worth noting, for the surface developments at this mine caused Russell to consider the Clinton ore to be merely a surface deposit. This early error has been followed by most text-book writers on economic geology, despite the fact that even a casual personal acquaintance with the district in its present condition would suffice to prove that it is an error.

Soft ores from surface workings near this gap gave McCalley the following results:

Analysis of soft ores near Attalla, Ala.

Silica	8.39
Metallic iron	53.92
Phosphorus anhydride	1.55

The hard ore from the Alabama Consolidated mines is still of very high grade for this district.

The Northern Alabama Mining Company has several surface cuts and one slope located on Moragne Mountain. The ore here varies from 34 to 40 inches in thickness, without parting, and dips at an angle of 23° to 26°. At some points soft ore has been found as far down as 300 feet, measured on the slope, equivalent to a vertical depth of 75 feet below the ground surface. The larger part of the ore now shipped is, however, hard ore.

The following analyses of hard and soft ores from the Moragne Mountain mines of the Northern Alabama Mining Company are by chemists of the Woodstock Iron Company:

Analyses of ores from mines at Moragne Mountain, Alabama.

	Soft ores.				Hard ores.	
Silica (SiO_2)	10.74	7.16	8.40	8.76	9.26	8.40
Alumina (Al_2O_3)	2.00	n. d.	n. d.	n. d.	n. d.	n. d.
Metallic iron (Fe)	51.02	52.56	51.90	52.75	43.88	38.05
Lime (CaO)	n. d.	n. d.	n. d.	n. d.	17.86	27.00

Red ore has been exposed by a prospecting pit on the Rhea place, about 2 miles west of Attalla. The ore at the outcrop is 27 inches thick, but much of it seems to be very sandy. The ore bed at this point strikes N. 10° E. and dips 80°–88° W.

Gadsden (*Shinbone Ridge*).—Several small mines were formerly worked at Gadsden, but the workings now in operation are located respectively 2 and 3 miles northeast of the town, on the southeast flank of Shinbone Ridge. The mine nearer town shows an ore bed 3½ to 4 feet thick, on which workings have been carried down about 200 feet. The farther mine (Etowah No. 2) shows an ore bed 2½ to 3½ feet thick, dipping 80° NE. and striking N. 42° E. This slope is now down about 200 feet. Both mines ship their product to the furnace of the Alabama Consolidated Coal and Iron Company at Gadsden.

Southeast of Gadsden red ores have been worked in earlier days on the ridges north and south of Rock Springs station. The beds here are usually 14 to 18 inches thick, though one opening is said to have shown a 3-foot ore seam. The ore lies above the heavy sandstone which caps these ridges.

Gaylesville (*Dirtseller Ridge*).—Extensive work is being carried on by the Southern Steel Company along the southeast flank of Dirtseller or Tuckers Ridge about 2 miles north of Gaylesville. Working slopes and prospect pits have developed the ore for a distance of 2 miles or so along the strike and give an excellent opportunity for its examination.

The northernmost slope—the Skeen slope—is at present the principal working. This slope is driven in the direction S. 40° E. and is run in on the dip of the ore, which is here 20°. The section exposed was as follows:

Section in Skeen slope, near Gaylesville, Ala.

	Inches.
Good solid ore	20
Mixed (shaly) ore	7

At the southernmost series of openings the dip is still 20° SE., but the ore bed is split by a heavy shale parting into two seams. Sections measured here are as follows:

Sections at southernmost openings near Gaylesville, Ala.

	1.	2.
	Inches.	*Inches.*
Ore	4	4
Shale	8	10
Ore	19	18

The three sections above noted are, it is believed, fairly representative of the conditions existing in this portion of Dirtseller Ridge. In places the ore thickens locally to 3 or even 5 feet, but on the other hand local thinning occurs at other points on the outcrops. It is probably safe to assume that the average thickness over the whole outcrop is between 20 and 24 inches.

As this particular area had never been worked to supply ore for the old charcoal furnaces, the Southern Steel Company has been able to secure a very large amount of soft ore of good grade from this property. Analyses of representative shipments of this soft ore by M. C. Shannon follow:

Analyses of soft ore from Dirtseller Ridge, Alabama.

	1.	2.
Silica (SiO_2)	13.70	15.87
Alumina (Al_2O_3)	5.86	5.87
Metallic iron (Fe)	49.70	49.55
Lime (CaO)	2.35	2.61
Phosphorus (P)	.44	n. d.

Most of the workings have now been driven deep enough to have passed through the soft ore into the hard, of which no analyses are available. Northeast of the Southern Steel Company's holdings red ore has been mined near Dewey post-office and at other points across the Georgia line.

THE IRON ORES OF BATH COUNTY, KY.[a]

By E. M. Kindle.

Introduction.—Bath County is located in the northeastern portion of the State just outside the blue-grass region. The topography of the southeastern portion is of the bold, hilly type characteristic of the Kentucky mountain districts. Rugged, steep-sided hills and ridges left by the dissection of the Lower Carboniferous sandstones are the dominant features of this section. These command a broad sweep of hilly but somewhat less elevated country which comprises the northwestern two-thirds of the county. The deeply incised and widely meandering channel of Licking River receives the drainage of the county and forms its northeastern boundary. Within the limits of this county occur all the main divisions of the geologic column which are developed in the State of Kentucky. The oldest rocks are the Ordovician, which outcrop in the northwestern part of the county. These are carried downward by a moderate southeasterly dip, resulting in a series of deeply scalloped belts of successively younger beds which cross the county in a northeasterly-southwesterly direction. The Coal Measures, which are the youngest rocks in the area, cap some of the hills near the southeastern boundary.

Geologic relations and character of the ores.—Iron ores occur at three distinct geologic horizons in Bath County. The Lower Carboniferous beds contain the highest or youngest of these ores. These Carboniferous ores lie in very thin beds, sometimes seven or eight in number, occurring usually as scattered kidney-shaped masses of iron carbonate in the shales. They have generally a thickness of only a few inches, but occasionally reach 1 or 2 feet. These ores are carbonates of low grade.

The expense of mining ores of this character, which, unlike the other ores of this county, can not be stripped, together with their rather high sulphur and phosphorus content, will probably make profitable mining of them impossible for some time to come.

The ores which were mined for many years at the Preston ore banks lie in a Devonian horizon,[b] holding a position between the Black shale and the Silurian beds. Iron ore is reported to occur locally at this horizon in small amounts to the southwest of Bath County in Montgomery, Boyle, Lincoln, and Casey counties. In Ohio, about 50 miles northeast of Bath County, the writer has observed iron ore which was formerly mined occurring at the same horizon southeast of Peebles. The belt of occasional ore deposits to which the Preston ore banks belong has therefore an extent of about 150 miles along the southeast flank of the Cincinnati geanticline. The Preston ore is an exceptional development of the thin lenticular and usually worthless ore masses occurring occasionally at this horizon. This ore was reported by Mr. Linney[c] to have a thickness of from 7 to 15 feet. It is a limonite and carries from 52 to 80 per cent of oxide of iron, according to Doctor Peters's analysis.[d]

The third and lowest ore horizon occurs in the Clinton shales. This ore bed seldom exceeds 4 feet and is frequently less than 2 feet in thickness. Several thousand acres to the east and southeast of Owingsville are probably underlain by the ore bed. Considerable areas occur where the land is sufficiently flat and the iron near enough to the surface to permit mining by stripping the overlying shales and shaly sandstone. This ore is a hematite of oolitic structure, the particles composing it being quite small and lenticular or flattened in shape. It does not anywhere appear to be a "fossil ore," the few fossils occurring in it being generally minute forms. A chemical analysis of the specimens of the Clinton ores made by Doctor Peters's [a] showed the following results:

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[a] The author is indebted to Mr. W. C. Phalen for the use of notes on the mines of the Rose Run Company.

[b] Report on Bath and Fleming counties, Kentucky Geol. Survey, 1886, p. 25.

[c] Report on the Geology of Bath and Fleming counties, Kentucky Geol. Survey, 1886, p. 28.

[d] Rept. Kentucky Geol. Survey, old series, vol. 4, p. 62.

Analyses of Clinton iron ores, Kentucky.

	1.	2.	3.
Iron peroxide	47.630	51.430	58.570
Alumina	5.468	5.132	3.720
Lime carbonate	16.560	13.080	15.160
Magnesia carbonate	9.974	9.444	4.528
Phosphoric acid (P_2O_5)	1.202	1.138	1.010
Silica	7.160	7.800	6.960
Moisture expelled at 212° F	1.143	.693	1.607
Undetermined carbonic acid, water, organic matter, etc	10.865	11.283	8.444
	100.000	100.000	100.000
Percentage of iron	33.341	36.001	40.999

The iron which this ore produces is described as a "soft fluid foundry iron, somewhat cold short."

Development.—The Bath County ores are of some historic as well as economic interest. As early as 1791 an iron furnace was in operation on Slate Creek, 2 miles south of Owingsville. Here charcoal iron was produced for nearly half a century and shipped down Licking River to various trade centers of the Mississippi Valley long before railways had become factors in the commerce of the Central West. The iron produced here, owing to the high percentage of phosphorus in the ore, was a hard but not very tenacious metal. Cannon balls which were made from Bath County iron for the war of 1812 may still be seen in some of the curio collections of Owingsville. On the expiration of a lease this furnace went out of blast and was never reöpened. The old furnace is still standing—a monument to the part played by Kentucky in the early development of the iron industry.

At a later period the Preston ore banks, which supplied this furnace, were reopened by the Slate Creek Iron Company, which shipped the ore for smelting until the supply was exhausted. In 1838 a furnace was erected on Caney Creek. Iron was made here from the Lower Carboniferous ores for some years, charcoal being used as a fuel. The venture does not appear to have been a profitable one, and no attempt has been made to utilize these ores in recent years.

At the time of the survey of this county by the Kentucky Geological Survey in 1885 the Clinton ores had not been developed. These ores have since been extensively mined and are at present the only ores worked in Bath County. The Rose Run Iron Company is engaged in mining them. The mines are located about 3½ miles east of Owingsville, and are connected by switch with the Chesapeake and Ohio Railway at Olympia. The ore is stripped, a part of the stripping being done by a steam shovel. Formerly the ore was smelted at the mine, at present it is shipped for reduction. The ores are transferred from the mine breast to the tipple by a small locomotive and cars. Fifty men are employed, and an average of about 125 tons of ore per day are produced. The ore is used for pig iron, and is shipped to various points for reduction. Some of the furnaces which are using it or have used it are located at Ashland, Ky.; Ironton, Ohio; Lowmoor, Va., and Big Stone Gap, Va.

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[a] Report on Bath and Fleming counties, Kentucky Geol. Survey, 1884, p. 19.

Approximately 25,000 tons of ore were produced during the year 1905. The mine section as exposed at one point shows the following beds:

Section at mine of Rose Run Iron Company near Owingsville, Ky.

	Feet.
Yellow surface clay	2
Thin-bedded sandstone and shale	5
Blue clay shale	6
Iron ore	4

The ore varies in thickness from 1½ to 5 feet, 2 feet being perhaps an average. About 5 inches of green ore generally overlie the red ore. This 5-inch band carries a percentage of sulphur, which necessitates roasting before it can be used. It was formerly roasted at the mines, but at present it is thrown out. The high percentage of lime in the ore makes it unnecessary to add lime for fluxing. A series of 5 analyses, made by different parties, show the lime content to run from 8.86 to 11.91 per cent, and the silica from 4.19 to 8.73 per cent. The same analyses show the iron to run from 35.7 to 38.6 per cent; magnesia, 4.08 to 5.84 per cent; alumina, 3.54 to 6.80 per cent, and phosphorus, 0.43 to 0.61 per cent.

About 15 acres of the ore have been worked out. The yield of ore per acre is estimated at about 3,000 tons per foot of thickness. The Clinton ore which has been mined may therefore be estimated at approximately 125,000 tons. There are probably several thousand acres of the Clinton ore of about the same grade and thickness as that which has been mined. Only a small percentage of this can be mined by stripping, however.

With the rapid exhaustion of the supply of high-grade ores and the consequent increase in the demand for ore of this grade which may be expected in the future, much of the Clinton ore which can not now be profitably mined may eventually be utilized.

THE ORISKANY AND CLINTON IRON ORES OF VIRGINIA.

By Edwin C. Eckel.

INTRODUCTION.

During the year 1905 work was carried on by the United States and Virginia Geological Surveys, acting in cooperation, on the iron ores of Virginia. This work was placed in charge of the writer, who also did most of the actual field work on the Oriskany and Clinton ores, while Mr. R. J. Holden, of the Virginia Survey, did all the work on the New River-Cripple Creek brown ores and spent some time in the Oriskany district. Mr. J. S. Grasty carried out areal mapping in the Oriskany district, covering a few small areas left unmapped by Prof. H. D. Campbell, who in previous years, and largely at his own expense, had made detailed maps of most of this region. Professor Campbell kindly placed these earlier results at my disposal, and exercised general supervision over Mr. Grasty's field work.

Detailed reports on the work above mentioned are now in preparation and bulletins on the iron ores of Virginia will be issued independently by the Federal and State Geological Surveys as the field work in the different districts is completed. In the following pages brief notes are given on the work so far accomplished in certain important districts. The relations of these various pieces of field work to one another can be best understood if the reports are prefaced by an introductory statement as to the ore districts of Virginia.

IRON ORES OF VIRGINIA.

Considered from either an industrial or geologic view point, the iron ores of Virginia fall into 6 groups:

I. Magnetites and specular hematites of the Blue Ridge and Piedmont districts.
II. Red hematites (Clinton ores, "fossil ores," "oolitic ores") of the foothills of the Allegheny Mountains.
III. Brown hematites (Oriskany ores) of the Goshen-Longdale-Lowmoor-Oriskany district, mostly in Augusta, Bath, Botetourt, Alleghany, and Craig counties.
IV. Brown hematites of the New River-Cripple Creek district, mostly in Wythe and Pulaski counties.
V. Brown hematites of the Roanoke, Shenandoah, and Page valleys.
VI. Brown hematites ("gossan ores") of Carroll and Floyd counties.

During last season detailed field work was done on the ores of classes III and IV, the ores of class II were examined in less detail at several localities, while on those of classes I, V, and VI no field work was done. It is planned to complete the work during 1906 by examination of the ore deposits not visited during 1905.

ORE RESERVES AND IRON PRODUCTION.

The most striking fact brought out by the work of last year is the small amount of workable ore now in sight. Few of the furnaces are in an entirely satisfactory position as regards ore reserves, while several have only a few years' supply available. Most of the brown-ore districts worked ten years ago are now within measurable distance of exhaustion and new deposits are not being developed rapidly enough to offset the drain on the older beds. Several rich deposits of the Oriskany brown ore have been opened within the last year or two, but elsewhere little of promise has been uncovered.

In the face of such conditions as to brown-ore supply, it would seem wise to commence active and careful exploration of the other two classes of ore known to exist, in workable quantities, in the State. These are (1) the Clinton red or fossil ores of western Virginia, and (2) the magnetites of the Blue Ridge and Piedmont districts. Neither of these classes of ore has as yet been given proper consideration.

At present from 100,000 to 200,000 tons of ore are shipped into Virginia furnaces from Tennessee, North Carolina, and the Lake Superior districts, a fact which must be borne in mind when comparing the iron-ore and pig-iron statistics given later. Lake Superior ores cost from 8 to 10 cents per ton per unit of iron when they reach the Virginia furnaces, as compared with 3 to 5 cents per ton per unit for the native brown ores.

The following data in cost of iron production in various States have been calculated from figures given in the reports of the Twelfth Census (1900). The total costs as here given include raw materials (ore, fuel, flux, etc.), wages, salaries, and repairs.

Cost of production of coke iron, per ton, 1900.

Alabama	$8.12
Tennessee	9.97
Illinois	10.12
Pennsylvania	11.23
Virginia	12.12

The Alabama and Virginia costs above given have been checked with a number of detailed cost sheets kindly furnished by several companies in those States, and it is believed that the averages given can be accepted as correct enough for present purposes. They may, at any rate, be profitably compared with the estimates to be found in prospectuses.

The iron-ore and pig-iron production of Virginia are summarized for the years 1899 to 1905, inclusive, in the following table:

Iron-ore and pig-iron production of Virginia and West Virginia.

Year.	Brown ore.	Red hematite.	Magnetite.	Total iron ore.	Total pig iron.
1899	968,143	17,173	1,160	986,476	365,491
1900	918,157	3,664	....	921,821	490,617
1901	910,214	13,156	2,024	925,394	448,662
1902	953,128	31,677	3,153	987,958	537,216
1903	764,948	31,069	4,604	801,161	544,034
1904	528,853	17,952	3,448	550,253	310,526
1905	[a]702,000	[a]45,000	[a]3,000	[a]750,000	510,210

[a] Estimated. All other figures are exact.

ORISKANY BROWN ORES.

In the counties of Allegheny, Augusta, Rockbridge, Bath, Botetourt, and Craig, and, to a less extent, in other areas of central-western Virginia, large deposits of brown iron ore are associated with certain beds of the Silurian rocks. The deposits are frequently overlain by the Oriskany sandstone, and most observers have considered the ores to be original deposits in that formation, so that the term "Oriskany ores" has come into common use. Careful examination, however, shows that the ores are replacements, mainly of the "Helderberg" or Lewistown limestone, but also of the adjacent beds of the Oriskany. As a matter of convenience the term "Oriskany ores" may well be retained, even though it is somewhat misleading.

Early in the field season of 1905 the writer commenced work on the ores of this district, studying their occurrence, character, and origin. After the completion of this general work, Mr. R. J. Holden, of the Virginia Geological Survey, was detailed to map certain of the more important ore deposits on a large scale, while Mr. J. S. Grasty took up general geologic mapping of several adjoining areas. Prof. H. D. Campbell, of Lexington, Va., kindly gave the use of his geologic maps of the district, and in addition exercised general supervision over the areal work of Mr. Grasty.

General geology of the district.—The rocks exposed in this district are of Devonian and Silurian age, the ores being associated with the uppermost Silurian and basal Devonian formations. The formations are as follows:

Geologic formations in Oriskany district.

	Thickness in feet.
Devonian black shales	1,000–2,000
Oriskany sandstone and siliceous limestone	50– 250
Lewistown ("Helderberg") limestone	300– 800
Rockwood (' Clinton") shale and sandstone	300– 600
Clinch ("Medina") quartzite	50– 150

The above generalized section will cover the variations in thickness shown in different parts of the district. It may profitably be compared with a carefully measured section shown at a point near the middle of the ore-bearing area.

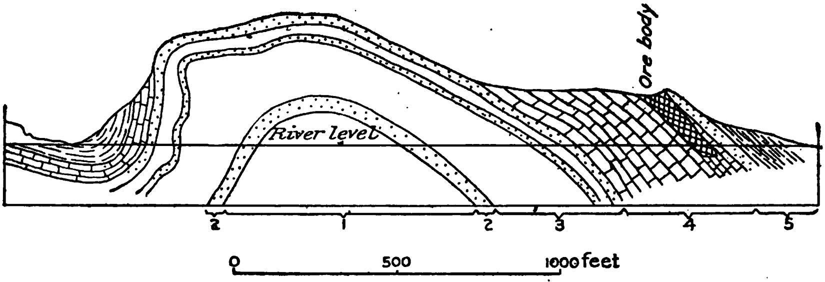

FIG. 8.—Generalized section at Iron Gate, Va.

The following section was measured in 1905 by E. O. Ulrich at Iron Gate, Va.:

Section at Iron Gate, Va.

			Thickness in feet.
Devonian black shales			(?)
Oriskany	a. Calcareous sandstone	50	209
	b. Siliceous limestone, with many beds of chert	54	
	c. Bluish-gray limestone, with sandy beds in upper part	65	
	d. Quartzitic sandstone, with two shaly beds	40	
Lewistown ("Helderberg")	Thin-bedded shaly limestone shales		322
Rockwood ("Clinton")	a. Heavy sandstone	42	452
	b. Alternating sandstone and shale	125	
	c. Sandstones and shales, overlying a red and white mottled shale; with a heavy ferruginous sandstone ("block ore") near base	115	
	d. Shales, with fossil ore bed near top	170	
Clinch ("Medina")	Hard, massive white sandstone		50

Structure of the district.—In the Oriskany district the rocks above described have been thrown into a series of parallel folds, trending about N. 35° E. These folds are not symmetrical, for they show low dips (5° to 25°) toward the southwest, while the northeastward dips are steep—from 60° to vertical, and sometimes even overturned slightly. After this folding erosion removed the less resistant beds from the more exposed portions, so that now the crests of the ridges are made up of the hard "Clinton" and "Medina" quartzites and sandstones, while the "Helderberg" and Oriskany beds outcrop on the slopes and in the valleys are covered by the Devonian shale. These structural conditions, as will be seen later, exercised a very marked influence on the localization of the ore bodies.

Occurrence of the ores.—The iron ores of this district are brown ores, occurring in bed-shaped deposits, continuous in length on the outcrop for considerable distances.

The ore bodies usually outcrop on the southeast flanks of the ridges, from 200 to 400 feet above the valley bottoms. Near the outcrop they are overlain either by sandstones of Oriskany age or else directly by the Devonian black shale. They are immediately underlain in most cases by a bed of cherty clay, which in turn rests upon "Clinton" sandstone or shale. As the ore bodies are followed deeper it is found that they thin somewhat and that limestone appears in one or both walls of the deeper workings. It is to be expected that finally the ores will entirely disappear in depth, their place being taken by continuous beds of limestone.

When for any reason the Lewistown ("Helderberg") limestones appear in several parallel outcrops, the ore bodies are likely to be similarly duplicated.

At the lower or southwest end of the Dolly Ann property northeast of Covington, for example, the ore beds are seen to occur in three parallel synclinal basins, thus giving six distinct lines of outcrop of the ore. Farther northeast only the easternmost of these basins persists, the other two dying out owing to cross folding. Similarly, to the southwest the easterly basin is cut off by limestone near Jackson River, but occurs again south of the river, while the two westerly basins are cut off some distance north of the river and do not reappear. The ore in this area varies from 3 to 32 feet in thickness, probably averaging about 12 feet over the entire property. It lies on a foot wall of loose chert or cherty clay, which is usually about 1 foot thick, but in places 5 to 6 feet. In most of the openings the ore is capped by 10 to 20 feet of yellow sandstone, which is in turn overlain by the black Devonian shale.

Opposite the company store the remains of the old Dolly Ann furnace stand on an ore bank which shows the following section:

Section at ore bank near Covington, Va.

	Feet.
Pebbles, gravels, etc	6
Bluish to black shale	4
Yellow-brown crumbling sandstone	18
Brown ore	10 +

Origin of the ores.—The Oriskany ores have been usually described as being original deposits or as having originated through the weathering and hydration of carbonates which were deposited with the limestones and sandstones that now inclose the brown ores.

In the final report on these ores the question of origin will be taken up in some detail and the reasons for the writer's conclusions will be stated more fully. Here it is possible only to state the main results briefly.

The workable ores are undoubtedly of much later origin than the rocks which now inclose them; and the ore deposits occupy spaces formerly filled by Lewistown and Oriskany limestones and sandstones.

There seems to be little reason to believe that much of the ore has originated by the replacement of limestone by iron carbonates and the subsequent hydration of this carbonate. It is true that iron carbonate has been found at several points in the deeper portions of the Longdale mines and it may be found in other mines of the district. But in general it seems certain that the ore was deposited directly as brown hematite. The deposition was in part simply a filling of cavities in the limestone, but most of the deposition probably followed the solution of the limestone so closely as to amount practically to a replacement process.

Character of the ores.—The ores usually range from 32 to 36 per cent of metallic iron and are commonly very high in silica.

An analysis of the Dolly Ann ore, by H. L. Morris, follows. It is typical of the material shipped to Lowmoor furnace, and is fairly representative of the Oriskany ores in general.

Analysis of ore from Dolly Ann property, near Covington, Va.

Silica (SiO_2)	33.26
Alumina (Al_2O_3)	5.26
Iron oxide (Fe_2O_3)	52.86
Manganese oxide (MnO)	.61
Lime (CaO)	.28
Sulphur (S)	.014
Phosphorus anhydride (P_2O_5)	1.312
Carbon dioxide (CO_2)	.21
Water (H_2O)	1.90

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THE CLINTON, RED, OR FOSSIL ORES.

The Clinton ores of Virginia are not particularly well developed, as regards either quality or thickness, and so far have attracted little attention. But the gradual exhaustion of the supply of good brown ores is operating to create interest in the Clinton ores at present.

The Clinton ores have recently been opened by the Lowmoor Iron Company along the southeastern face of Horse Mountain, about 3 miles southwest of Lowmoor station. The ores here outcrop near the crest of the ridge and dip about 10° into it. When visited by the writer in June, 1905, several slopes had been run in, the workings having progressed for 100 to 130 feet in each slope. Sections of the ore and associated rocks were carefully measured at the entries of two of these slopes, with the following results:

Section on slope 1, near Lowmoor, Va.

	Ft.	In.
White quartzite	35	
Shale		2
Sandstone		3
Shale		½
Sandstone		3
Shales and thin sandstone		10
Fossil ore, brown and porous		7
Fossil ore, red and fairly hard		14
Ochery clay		6
Shales	2	

The brownish fossil ore in this section was said to average about 40 per cent and the red ore about 56 per cent without washing. Another slope gave the following section:

Section on slope 2, near Lowmoor, Va.

	Ft.	In.
White quartzite	30	
Shales		2
Red fossil ore	1	4
Ochery shales and thin sandstones	1	
Shales and sandstones	2	

The ore is hand picked at the mines to clear it of slate, and then run down an incline to the cars below. An analysis of the red ore from these mines, by H. L. Morris, chemist of the Lowmoor Iron Company, is as follows:

Analysis of red ore from mines near Lowmoor, Va.

Metallic iron (Fe)	57.00
Manganese (Mn)	.15
Silica (SiO_2)	7.12
Aluminum (Al_2O_3)	6.31
Lime (CaO)	1.46
Magnesia (MgO)	.08
Phosphorus anhydride (P_2O_5)	1.54
Carbon dioxide (CO_2)	1.23
Water (H_2O)	1.18

From this analysis it can be seen that the ore so far handled is a thoroughly leached ore—a "soft ore," to use the Alabama term. Its lime carbonate has been almost entirely removed and in consequence its iron percentage is relatively high. Farther under cover the ore will become hard and probably fall to 35 per cent or less of metallic iron.

The Clinton ore has been mined in the river gap at Iron Gate, but the beds are very thin and irregular and the unleached ("hard") ore is of very low grade. The following analyses have been furnished by the Longdale Iron Company:

Analyses of Clinton ore from Iron Gate, Va.

Metallic iron	46.5	46.0
Insoluble	19.90	20.24
Phosphorus	.49	.48

The beds examined here are rarely over 8 to 12 inches thick, and as practically all the soft or leached ore has been used, the deposits can hardly be regarded as of commercial value.

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THE BROWN ORES OF THE NEW RIVER-CRIPPLE CREEK DISTRICT, VIRGINIA.[a]

By R. J. Holden.

Location.—The New River-Cripple Creek area includes most of the limonites of the valley region. The area in which ores are now mined lies chiefly in the southwestern part of Pulaski County and the southern part of Wythe County. It is a narrow strip of territory about 3 miles wide and 55 miles long and lies on the southeastern side of the Great Valley near the foot of the mountains.

Geology.—The rocks with which most of these ores are associated are of Cambrian and Ordovician age. The chief rock is the Cambro-Ordovician limestone, which is here dolomitic through many of its phases and which contains considerable interbedded red shales. While in a major way this formation conforms to the structure described later, in a minor way it is complexly folded and somewhat faulted, so that its thickness is difficult to determine. Its southeastern border is only a few hundred feet thick, while toward the center of the valley it attains a great thickness. This formation furnishes the chief surface rock of the valley, which is here from 6 to 12 miles wide. Underlying the limestone is a Cambrian quartzite and under this in turn a shale. These latter formations are probably to be correlated, respectively, with the Erwin quartzite and the Hampton shale of the Cranberry folio. They form the main portion of the mountains to the southeast and appear in the valley in a few places as anticlinal ridges.

Structure.—Structurally the region is characterized by thrust faults, with the fault planes dipping to the southeast. These faults are apparently not very closely spaced, yet are sufficiently so to give to the strata their prevailing southeastward dip. The most conspicuous faults are those at the margins of the valley. On the southeast side the quartzite is locally faulted over onto the limestone. On the northwest side the limestone is thrust over onto the Devonian and Lower Carboniferous sediments. While faulting has been the dominant type of deformation, folding has not been unimportant. The Cambrian shows a number of anticlines. The mountain to the southeast is in the main anticlinal, as is also Lick Mountain, a valley ridge. There are a number of anticlinal ridges which extend into the valley as spurs of the main mountain. However, these anticlines show a tendency toward faulting on their northern sides.

Relief.—The region in which the ore territory lies is one of considerable relief. The crests of the ridges are from 500 to 1,500 feet above the valley floor and New River and its branches have cut down 200 to 300 feet below the general level of the valley. The topography is controlled by the rock structure, the southeastward dips having produced northeast-southwest ridges and valleys. The exception to this is the modifying influence of New River, which is an antecedent stream, cutting directly across the trend of the mountains. In the valley, while the streams have cut down several hundred feet, erosion has cut back from the stream courses in the softer strata, making the valley surface a series of oval domes.

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[a] This report is the result of cooperative work carried on in 1905 by the Virginia and United States Geological Surveys, and is here presented by permission of Mr. T. F. Watson, State geologist of Virginia. The relations of this particular area and report to the general problem are discussed on pp. 183-184 E. C. E.

Occurrence and character of the ores.—The residue from the decay of the limestone shows considerable variation in depth. In places it is so thin that the limestone is exposed every few feet, while in other places mining has shown it to have a depth of 80 feet. Where the residue is protected by overlying strata from the weight of other material, it can frequently be traced, stratum for stratum, into the limestone. It is perfectly certain that this material has its origin in the limestone. Solution of the limestone takes place very irregularly, and in consequence the surface of the unaltered rock is very uneven. Commonly these irregularities take the form of pinnacles or domes, varying from those which are small and closely spaced to larger ones 20 feet in diameter and 50 feet in height. The residue lies between these limestone "horses" and forms a cover over them from 5 to 20 feet thick.

In this iron-ore region the residue contains a large percentage of iron oxide. Most of this is in the form of fine particles, which give to the residue its deep-red color. Where the iron oxide takes the form of granules of such size that they will not pass a screen which has 12 meshes to the inch and the particles are present in an appreciable quantity, it becomes an iron ore. The individual pieces of ore may vary from the minimum size up to lumps several feet in diameter. Much of the ore consists of angular fragments which have been broken and moved from the position in which they were deposited from solution. A smaller portion of the pieces of ore have the form and position which they assumed when they were precipitated. The form of the pieces varies with the environment in which the precipitation occurred. The clay derived from the limestone is relatively pervious. Ores deposited in this material assume irregular shapes and, where the aggregates are of sufficient size, are generally cellular, frequently inclosing clay in the cavities. In a few instances the ore has been precipitated on the surface of the limestone itself. In such cases the ore laminæ are one-half inch or less in thickness and sometimes form closed spaces, including rectangular blocks of limestone an inch or so on a side. The residue from shale is relatively impervious. Iron oxide precipitated in or above this material, instead of having cavernous or honeycomb structure, is apt to occur in sheets of compact material 2 inches or less in thickness or in irregular, compact masses of greater size. Not only do these ores have a different physical appearance, but the impurities which they hold give them a somewhat different chemical composition. The ores occurring in the limestone residue are locally known as "limonites;" the shale and sandstone ores as "mountain" ores. There are a few mines whose ores have characteristics intermediate between these two classes and such ores are known as "semilimonites." Analyses furnished by the companies[a] operating these ores show the following content:

Analyses of iron ores from New River-Cripple Creek district, Virginia.

	Limonites.[a]	Semi-limonites.[b]	Mountain ores.[c]
Metallic iron	43.76	40.72	37.86
Silica	13.52	20.12	18.60
Alumina	1.79	1.81	2.32
Phosphorus	.17	.31	.40
Manganese	.58	.83	1.49

[a] Average of 56 analyses from 12 mines.
[b] Average of 15 analyses from 5 mines.
[c] Average of 17 analyses from 4 mines.

The "limonites" are relatively high in iron and low in silica, phosphorus, and manganese, The three first named are fairly constant from mine to mine, while the manganese varies between 1 and 0.1 per cent. The alumina values are bases on few determinations. These values will vary according to the thoroughness with which these ores are washed. In the "mountain" ores there are lower values in the iron content, while the silica, phosphorus, and manganese are higher. The manganese here varies between wider limits than in the

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[a] Virginia Iron, Coal and Coke Company; Pulaski Iron Company; New River Mineral Company.

"limonites." The "limonites" are throughout the more desirable ores. The ratio of the amount of ore to the total material of the bank varies widely. In some of the "mountain" ore mines the ore constitutes the larger portion of the material. In the "limonite" mines the ore content of the bank varies from 20 to 4 per cent. In other words, it is necessary to handle from 5 to 25 yards of bank to get 1 yard of ore. Samples taken by the writer from 20 mines show an average content of iron, computed to ferric oxide, of 44.59 per cent, with a variation between 63 and 23 per cent.[a] These samples were washed by hand and the fine material, which was removed in suspension, showed an average of 30 per cent ferric oxide.[a]

Origin of the ores.—It seems probable that these ores are concentrations of the iron which was originally disseminated in the Cambro-Ordovician limestone. It has been previously recognized[b] that the ores are associated with the lower measures of this limestone. In order to determine the possibility of the limestone being the source of the iron, it was sampled in the immediate vicinity of a producing mine, 180 samples being taken through a vertical thickness of 600 feet of the lower measures of the limestone. The average of the analyses[c] of these gave the following results for the more insoluble constituents of the rock: Silica, 1.74 per cent; metallic iron, 0.66 per cent; alumina, 0.50 per cent.

The following table shows a comparison between these analyses and that of the residue in the mine, including the ore. The percentages of the limestone analyses are reduced to the basis of 100.

Comparative analyses of limestone and residue from New River-Cripple Creek mines, Virginia.

	Insoluble matter in 600 feet of limestone.	Residue.
Ferric oxide	30	34
Silica	54	46
Alumina	16	....

The above comparison shows that, with the per cent of iron in the limestone as indicated by these analyses, a thickness of 600 feet of the limestone will contain a quantity of iron equal to that in the mine, the latter being estimated from the above analyses of the residue and from its thickness. As in this case several times 600 feet of limestone has been weathered, it is unnecessary to look farther for the source of the iron. Systematic sampling of the limestone has not been done over the region, but scattered analyses indicate similar conditions in regard to the iron content. In order to make a comparison with a region not iron-bearing samples were taken through about 300 feet of limestone at Staunton, Va. The analysis of this material shows that ferric oxide here constitutes 7 per cent of the insoluble portion of the limestone. This corresponds to the 30 per cent given for the Foster Falls region, which is iron bearing. The average content in ferric iron of twelve "limonite" mines is found to be 39 per cent. This is somewhat higher than at Foster Falls.

It is evident that there has been concentration of the iron in the residue by at least two methods. The first is essentially chemical. The body of the residue has a deep-red color, while the upper two feet are usually dark colored, but not red. This difference in color is believed to be due to the loss of iron by the upper portion. The reducing action of plant roots changed the ferric oxide to the ferrous condition and rendered it soluble. Percolating waters carried this down a few feet to a point where it was oxidized and precipitated. Erosion removed the leached portion until the ferric oxide was again within reach of the influence of vegetation. The process was repeated many times. Where iron was especially abundant or on steep slopes where erosion was particularly rapid, reduction and solution could not keep pace with the erosion and the red residue appeared at the surface. The process outlined above resulted in a concentration of the iron, which was removed from the sphere of surface erosion, while the other insoluble substances were exposed to it.

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[a] Analyses by J. H. Gibboney.

[b] McCreath, A. S., and d'Invilliers, E. V., The New River-Cripple Creek Mineral Region; a report to the president of the Norfolk and Western Railway, 1887.

[c] Analyses by J. H. Gibboney.

The other method of concentration in the residue was mainly mechanical. It is recognized by some of the leading mining men of the district that areas where limestone sinks are abundant are favorable for deep ore deposits. When the roof of a cavern in the limestone falls in the residue follows and a funnel-shaped depression is created. Into this the surface waters pour and remove in suspension the fine material and leave the lump ore. Abundant waterworn pebbles of a recrystallized quartzite occur normally at the surface of the residue. These are found at the bottom of the deepest mines. Apparently in some cases limestone sinks have been an important means of concentration of the ore.

If it is conceded that the "limonite" ores have their origin in the limestone, it is not necessary to go beyond this source for the origin of the ores which are now associated with the shales and sandstones. In this case all traces of the limestone except the ores have been removed and the ores let down upon the underlying rocks.

There are other ores in this region. On both margins of the limestone small deposits occur along the faults. The faults furnished a little better channel for water circulation, and the fault planes became the locus of a deposit, but these ores need not be distinguished in origin from the other ores with which they are associated.

At Radford Furnace, near the southeastern edge of this area, there is a deposit of limonite ore which, at one place at least, is associated with an iron carbonate. This ore may be the oxidized outcrop of a bedded carbonate. The mines have not been worked for some time, and the present limited showing prevents definite statements in regard to this point.

In Draper Mountain, on the northwestern border of this area, five mines are now in operation. This mountain is made up largely of Devonian and Lower Carboniferous sediments, chiefly sandstones and shales. Some of these ores are different in form, mode of occurrence, and chemical composition from the other ores. The Lower Carboniferous contains coal measures and considerable disseminated iron. This may be looked to as the source of the iron ore. The iron was carried in solution and deposited in favorable situations, which varied in their nature in the individual cases.

Near Abingdon are scattered deposits of ferruginous limestone, hematite, and magnetite which have been mined in a small way. The limestone as mined carried about 30 per cent of metallic iron. The deposits occur at the top of the Cambro-Ordovician limestone. Athens shales [a] lie in synclines of the limestone. The ores occur at the outcrop of the contact. Iron leached from the shale has been precipitated in the limestone as hematite and magnetite. At one place the limestone has been much brecciated, and here the iron has been irregularly deposited in the limestone both as ferrous and as ferric iron. The ferrous iron is clearly a replacement of the limestone.

Summary.—The iron ores of the valley region of southwestern Virginia, with one exception, are limonite. They occur in the residual clay and usually constitute about 7 per cent of this material.

Classified according to their probable origin, there are four classes of ores. Named in order of their importance they are as follows:

1. The limonite ores of the valley, associated with the limestone. Iron originally disseminated in the limestone.
2. The limonite ores of Draper Mountain. Iron leached from the Lower Carboniferous sediments.
3. The limonite ore at Radford Furnace. Oxidation in situ of carbonate of iron.
4. Hematite, magnetite, and ferruginous limestone near Abingdon. Iron leached from Athens shale.

Classes 1 and 2 are mined at present, and the average monthly production for the last half of 1905 was 20,000 tons [b] for the New River-Cripple Creek area.

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[a] Campbell, M. R., Geologic Atlas U. S., folio 59, U. S. Geol. Survey, 1899.

[b] This figure is based on records of ore shipments kindly furnished by the Norfolk and Western Railway.

IRON ORES OF THE WESTERN UNITED STATES AND BRITISH COLUMBIA.

By C. K. LEITH.

INTRODUCTION.

An insignificant part of the iron-ore production of the United States has come from west of Mississippi River—in recent years about 2 per cent. Nevertheless, in that vast region there are many ore deposits known and doubtless more to be discovered. Present economic conditions demand that the nature, extent, and availability of the ores of this region should be generally known. The present writer has given attention primarily to the geological relations and origin of the ores as affording a basis of comparison with present producing districts of the United States rather than to estimates of tonnage and study of present commercial conditions, although some incidental attention has necessarily been paid to these matters. In the fall of 1903 the iron ores of Iron County, southern Utah, were examined and a brief report published in the Economic Bulletin for that year.[a] The work of the past two field seasons, including detailed mapping of the Utah deposits, is summarized below.

GENERAL RECONNAISSANCE.

HARTVILLE, WYOMING.

In 1904 the deposits at Sunrise, in the Hartville district of Wyoming, were looked over. The facts observed correspond with the description by W. S. Tangier Smith in the folio on this district.[b] The ores occur in the Whalen group of limestone, quartzite, and quartzose schist, extending along the west side of Whalen Canyon, south and west of Fredericks, to Sunrise and Hartville. Ore is mined at present only at Sunrise. Here an open pit, with terraces rising toward the north, exposes the ore and its associated rocks. The foot wall on the west consists of banded calcareous and siliceous schists and cherts. Smith describes these as schistose quartzites. The writer's examination, both in the field and with the microscope, disclosed no positive evidence of their sedimentary origin, though he has no reason to doubt that Smith's conclusion is correct. These grade up into the ore through phases which in the Lake Superior country would be called ferruginous cherts. The hanging wall is of much the same nature. The structure of both the foot and hanging walls, whether it be bedding or schistosity, dips steeply to the east. Immediately to the east of the deposit, near the power house, and also to the southwest, are limestones of the Whalen series. Resting unconformably upon the ores and associated rocks are Carboniferous limestones and sandstones, forming an amphitheater, opening to the southwest, about the ores and associated Whalen rocks. The lateral extent of the ore to the northwest is hidden by the capping of Carboniferous sandstones and limestones. Drilling is said to have shown the extension of the ore beneath these rocks to a considerable distance. Here it will have to be won by underground methods.

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[a] Bull. U. S. Geol. Survey No. 225, 1903, pp. 229-237.

[b] Geologic Atlas U. S., folio 91, U. S. Geol. Survey, 1903.

The ores are soft and hard hematite somewhat similar to those of the Chandler mine, in the Vermilion district of Minnesota. There is present also a considerable amount of massive blue ore like that of the Soudan mine, in Minnesota. An abundance of botryoidal quartz, stringers of malachite and azurite, yellowish chert phases, and ferrous aluminum-silicate rocks appear as minor constituents of the ore. The iron content grades from 45 to 65 per cent. According to Mr. Ahbe, superintendent, there is some difficulty in close grading of the ores for shipment. The phosphorus is for the most part near the Bessemer limit. Some of it will run above 0.1 per cent.

Smith describes the ores as in the form of lenses in the Whalen beds. Several phases of the ore and rock possess striking similarity to altered carbonates in exhibiting irregular and spotted areas of limonite. These facts, together with the nature of the foot wall and hanging wall observed at the mine, and the presence of ferruginous cherts, suggest that the ore has developed by either the replacement or alteration of lenses of a carbonate formation within the Whalen beds. In this connection Smith says that the limestone of the belt to the southwest contains a considerable amount of ferrous iron. Detailed studies should be made of the relations of the ore to the limestones and so-called schistose quartzites and the true nature and structure of the series determined. For purposes of folio mapping Smith was obliged to treat the Whalen beds as essentially a structural unit, though its petrographic phases were described and their approximate distribution outlined.

This deposit is the only one the writer has seen in the West which suggests possible similarity in lithology, origin, and relations of adjacent rocks to certain of the Lake Superior ores.

WASHINGTON.

Visits were made in 1904 to ore deposits in Stevens County, northeastern Washington. Southeast of Northport, near Deep Creek Lake, both northeast and southwest of the lake, yellow porous limonite occurs associated with limestone, resting on the flank of the mountains. The ore is exposed in a considerable number of pits and drifts. On the way to the area the cores of the mountains were observed to be granite flanked by limestone. No igneous rock was observed near the ore, but presumably, from the general structure of the region and analogy with other districts, it occurs not far away.

About 14 miles west of Valley is a shaft 75 feet deep from which have been thrown out fine dense hematite, coarse amphibolitic martite ore, and gradations between the two; also green schistose rocks whose relations to the ore were not determined. To the east sericitic slates may be seen dipping under the shaft and to the west are limestones, presumably forming the hanging wall.

To the southwest, on the Rogers's claim, several drifts were observed penetrating limestone with a small amount of hematite near the surface, suggesting a surface replacement of the limestone. Higher up the hill ferruginous slate and magnetitic slate, locally called jasper and indeed somewhat resembling jasper, are exposed. The relations to the limestone are unknown. Diorite was observed along the road in such relations as to indicate its lower stratigraphic position. From what the writer observed and from discussion with local prospectors, there is apparently in this region more or less ferruginous alteration of the limestone near its base, where it rests on slate. The occurrence of diorite intrusives in the vicinity suggests a possible genetic relation.

About 6 miles east of Valley limonite occurs between andesite forming the core of the large hill and limestone resting upon its flank. The ore is in general soft, hydrated hematite and limonite of red and brown colors, and very porous. Locally the ore seems to dip toward and under the andesite, which is spoken of as the hanging wall. There is evidence here also of some brecciation, faulting, and folding, some of it later than the formation of the ore. Near the contact with the ore both the andesite and the limestone are much altered and are represented by clay showing the texture and structure of the original rock. Stringers of the ore run both into the limestone and into the andesite. For the most part the contacts are very sharp. The extent and shape of the deposit has not been determined. A thickness of 20 feet was observed in one place and less in others.

VANCOUVER AND TEXADA ISLANDS, BRITISH COLUMBIA.

The best-known sources of iron ore for the northwestern United States are Texada Island and the west side of Vancouver Island, British Columbia, especially near Barclay Sound. The furnace at Port Townsend, Wash., has drawn its ore from the first of these localities and in plans for the use of this ore American capital has largely figured. Each of these localities was visited in 1904.

Without going into detailed descriptions, it may be reported that these ores are largely magnetite, carrying usually considerable amounts of iron and copper sulphides, apatite, amphibole, and garnet. At the surface is an oxidized zone, usually a few inches thick, of limonite and white sulphate. The metallic-iron content averages from 35 to 60 per cent and above in different deposits, the Texada ores and a part of those on Barclay Sound having the higher percentages. The sulphur content is for the most part high, requiring that the ores be roasted. The copper content is also high, particularly in the Texada ores (2 per cent). The phosphorus in the higher grade ores is mainly below the Bessemer limit.

The ores occur at or near the contact of acid igneous rocks with limestone and are obviously replacements of limestone. In some instances the ore may be seen entirely surrounded by igneous rock, evidently a replacement of limestone intruded by and caught up in igneous rock near the contact. The contacts of the igneous rock with the ore are characteristically sharp and present no gradation features that would accord with the view that the ore represents segregations from igneous rocks. The abundant occurrence of lime garnet, however, both in the ore and in the crystalline limestone adjacent to the igneous contact, suggests the concentration of the deposit under the influence of igneous intrusion. The shape, size, and vertical extent of the deposits have for the most part not been determined, but it is obvious that a large tonnage of iron ore is here to be obtained. In the Barclay Sound area several pits and tunnels have penetrated ore from a few feet to a maximum of 110 feet horizontally and approximately the same amount vertically. In Texada Island belts have a maximum thickness of about 100 feet and in one place a belt has been cut by a tunnel 300 feet below the surface. Here the ore is as wide and apparently of as good a grade as at the surface.

COLORADO.

In company with C. R. Van Hise a reconnaissance was made in 1905 of the iron ores south of Ashcroft, in Pitkin and Gunnison counties, near White Pine, Gunnison County; and in the Cebolla district, also in Gunnison County.

About 6 miles south of Ashcroft iron ores appear on both sides of the Elk Mountains divide, near its junction with the Saguache Range, in Pitkin and Gunnison counties. At "Cooper's," on the northwest side of the divide, at an elevation of between 11,000 and 12,000 feet, the iron lies on the steep face of the ridge. It is apparently underlain and overlain by limestone, and stringers of it may be seen extending into the limestone. The dip of the iron belt seems to be down the slope. Eight tunnels have been driven into the iron, the longest one 122 feet and the shortest 40 feet in iron. The vertical distance between the highest and lowest tunnels is between 75 and 100 feet. The greatest distance between the tunnels along the slope is 300 feet. The iron may be seen to extend along the slope for about 500 feet. These figures are not exact. Specimens taken at random showed a metallic-iron content varying from 30 to 64 per cent, phosphorus 0.007 to 0.069 per cent, and sulphur 0.077 to 0.970 per cent. The bulk of the ore is high in iron and sulphur and low in phosphorus. The iron at the surface is magnetite, with cavities filled with secondary limonite and quartz. Back in the tunnels the ore becomes harder and contains unaltered sulphides, garnet, epidote, and feldspar, suggesting original concentration under the influence of igneous rocks, which appear on the adjacent ridges.

On the southeast side of the divide the iron ores, supposedly continuous with those of the northwest side, extend in a belt along the east side of Taylors Peak and reappear on Crystal Peak and Mount Tilton. They were examined at Taylors Peak, the principal occurrence, where they lie both parallel and transverse, mainly the former, to the bedding of Carboniferous and Silurian limestones and shales dipping westward into the mountain. These rocks are underlain by a thin layer of Cambrian quartzite and this in turn by the "Sawatch" granite, which appears on the lower parts of the steep erosion slopes of the mountain. The overlying rocks are fine-grained diorites of recent age. The ore probably occurs in more than one layer, but how many the explorations do not show. At Taylors Peak a vertical pit 40 feet deep has been sunk in the ore. The dip of the ore while probably westward, was not determined at the pit, so that the thickness of the belt can not be estimated. The ore is here mainly a magnetite containing iron sulphide and chlorite. At the surface it is oxidized to limonite, which appears abundantly on the lower slopes. A single specimen collected here to show the nature of the ore carries 48.36 per cent of iron, 0.007 per cent phosphorus, and 5.88 per cent sulphur, but the average of the hole is said to show better-grade ore. A tunnel is now being driven into the underlying blue limestone in search for silver and lead.

Like the ore on the northwest side of the divide, the concentration of this ore under the influence of igneous rocks is apparent. It is said to be continuous with the ore on the northwest side; indeed, ore can be seen extending to the divide on each side. This would give the belt an approximate length of a mile, with a maximum width of 122 feet, as shown in one of the tunnels on the northwest side of the divide, but with an average width probably much less. The depth is unknown.

A visit was made to the iron-ore deposit about three-fourths of a mile northeast of the village of White Pine, Gunnison County. It occurs on the east slope of the valley, on a spur of the Saguache Mountains. The ridge has a granite core and carries on its slope Cambro-Silurian quartzite and limestone, dipping westward down the slope. The ore is at the contact of the limestone and quartzite, apparently replacing both. The dip of the ore seems to be parallel to the slope, although locally it dips into the hill, perhaps as a result of creep. Six tunnels crossing the ore were examined. One tunnel showed two seams 14 and 75 feet in width. The ore was not followed along the strike for any great distance, but it is said to extend to Marshall Pass, several miles away. The ore is crystalline magnetite and hematite containing epidote, garnet, and some iron sulphide, but not in large amount. At the surface it is altered to limonite, hematite, and clay. In some of it fragmental quartz grains may be seen. A sample analyzed by Chauvenet averaged 58.75 per cent in iron and 0.04 per cent in phosphorus. An average analysis of ten samples published by Birkinbine gives 59.32 per cent in iron, 0.036 per cent in phosphorus, and 7.9 per cent in silica.

Iron ores were examined along the north side of Cebolla Creek, about 15 miles south of Iola station, on the Denver and Rio Grande Railroad. Here there is an amphitheater of granite opening out to the southeast diagonally across the creek, partly inclcsing quartzite and above this limestone, iron carbonate, and iron ore. On the northwest trachyte flows cap both the granite and the sedimentary rocks. The limestone, iron carbonate, and iron ores appear principally in three small east-west hills arranged en échelon north of the creek. The limestone may be seen to grade up into iron carbonate or ferriferous limestone or dolomite, which constitutes most of the central hill, the west end of the western hill, and an unknown part of the eastern hill. This iron carbonate varies from fine to coarse grained and is intimately interbanded with magnetite and hematite, suggesting contemporaneous origin. Whether the iron carbonate and its associated iron oxide consists of an original sedimentary formation conformable with the limestone below or is a result of subsequent alteration aided by igneous agencies was not determined. In favor of the former is its fine grain in places and apparent conformability with the limestone. In favor of the latter is its local coarsely crystallized character and the occurrence of this coarser carbonate in distinct veins. At the surface the carbonate is altered to limonite and clay, with the development and introduction of chlorite, chalcedony, and manganese oxide. One specimen here taken runs 45.92 per cent in manganese. This alteration is confined principally to the localities adjacent to the overlying trachyte capping, especially near the east ends of the western and central hills. Solution cavities here are almost certain evidence that waters heated by the trachyte, similar to those now coming from it on the south side of the gulch and in one spring depositing limonite, were the agents of the alteration.

The limonite and other alteration products of the iron carbonate, together with the residual magnetite and hematite which were originally associated with it, constitute the ores of this area. The principal showing of ore is on the east end of the western hill. Here several drifts have been run into the hill. The ore may be seen to extend along the hill for 500 or more feet, and into the hill horizontally for 50 feet. The ore consists of nodules and irregular masses of limonite, magnetite, and hematite lying in an iron-stained matrix of clay and carrying abundant secondary chlorite or talc. It is much broken and contorted. Beneath the surface the harder nodules disappear and the ore is principally soft limonite or hematite, with clay and some magnetite. The best of the ore is said to run 55 or 60 per cent metallic iron, but the average published by Birkinbine is 35 per cent. Several published analyses show phosphorus below the Bessemer limit, but much of the ore is said to run higher. Sulphur is low in both the main body of the ore and the oxidized portion.

On the central iron-carbonate hill several tunnels have been driven into the hill to a distance of 100 or more feet. The oxidation of the iron carbonate may be seen to extend but a few feet into the hill.

In two localities titaniferous magnetite was observed. One is to the northeast of the central hill, between this hill and the trachyte, where it is shown in a pit associated with an altered greenish rock now represented only by large mica plates and some feldspar in a clayey matrix. The other locality is across the creek from the springs just east of the bridge, where there is a belt fully 50 feet wide apparently running up the slope for 100 feet or more. This has been opened at one place. One specimen taken here showed 42.71 per cent iron, 0.002 per cent phosphorus, 0.009 per cent sulphur, and 4.15 per cent titanic acid. No associated rocks are visible, but the magnetite contains narrow bands of greenish amphibole, partly altered to asbestos. It may be that the associated rock is the basic granite to be seen in the creek bottom beneath the bridge.

CALIFORNIA.

A visit was made to the Cave Canyon iron area, about one-fourth of a mile north of Scott station, on the San Pedro Railroad (Cave Canyon mines). It lies on the south side of the hills, between a complex of acid and intermediate rocks on the north and coarsely crystalline marble on the south, dipping southward at about 30°. The iron is mainly along the contact, but apparently projects into the igneous complex below and into the marble above. Little patches of marble were seen in what was taken to be iron ore. The exposure is much broken and covered by desert varnish, with the result that the surface distribution is not at once obvious. While the iron-ore débris covers the slope, in several places the igneous rocks appear through it. The ore occurs in two belts, one along the trend of the other, but separated by an erosion valley. The western belt is about 2,000 feet long and the eastern 1,700 feet long. The width of outcrop reaches a maximum of 450 feet. Its average width for the western belt may be 300 feet and for the eastern belt 100 feet. The true thickness of the ore body, assuming that it follows approximately the contact of the limestone, is probably less than half the width of outcrop because of the southward dip of the formation and the fact that the erosion slope follows the dip. Four tunnels are reported on the property. Two were seen in ore, the longer one 30 feet in length. The ore is mainly red hematite and limonite, soft and broken, showing limestone bedding. In one of the western tunnels green iron silicates were observed in the ore. The ore was not sampled. Commercial analyses from two sources show a percentage of iron above 60 per cent and phosphorus within the Bessemer limit.

DETAILED MAPPING IN UTAH.

During the summer of 1905 detailed mapping of the iron ores of Iron County, Utah, was begun by C. K. Leith, with the assistance of E. C. Harder and F. J. Katz, who continued the work independently during the fall. The iron ores, extending in narrow and discontinuous belts for a distance of about 18 miles northeast and southwest, were mapped with plane table on the scale of 250 feet to the inch, all pits and exposures (numbering 700 to 800) being shown. The total area so mapped was 5½ square miles. Pits and tunnels were measured and an attempt made to estimate tonnage. On the completion of the topographic base, the geology of a somewhat wider area will be mapped during the present winter and the report and maps will be submitted at an early date thereafter.

The ores appear on the erosion surface at or near the contact of intrusive andesite laccolites with limestone and sandstone and in one instance conglomerate; also in veins in the andesite itself. The ore is clearly a replacement of the limestone or an infiltration in veins in the other rocks. Evidences of two and perhaps three periods of concentration were observed. Under the influence of intrusion of the andesite laccolites iron carbonate, iron sulphide, and magnetite developed locally along contacts. During the subsequent erosion there seems to have been a further concentration, consisting in alteration of the carbonate and sulphide to hydrated oxide and perhaps further replacement of limestone by the hydrated oxide. These two concentrations have not yet been certainly separated and there is a possibility that they are really but one. The last and most conspicuous concentration occurred under the influence of later lavas which were poured out upon the eroded edges of the series, resulting in the coarse recrystalization of the ores, the development of magnetite and siderite, and the deposition of apatite and quartz, leaving the ores substantially as we now find them, though in the subsequent weathering they had been broken down and covered with desert varnish.

The ore at the surface is thus, because of the last concentration, predominantly magnetite and hematite containing chalcedonic quartz and a considerable amount of apatite in crystals sometimes reaching a length of 2 or 3 inches. Beneath the surface the ore becomes a soft blue and red hematite with subordinate quantities of magnetite. The average percentage of iron varies widely from 45 to 66. A large tonnage will average above 50 per cent. The phosphorus, for the most part, averages above 0.1 per cent.

The depth to which the ores extend along the inclined (30°) contact of the andesite and limestone is not yet known. Pits have shown it to extend for 150 feet in depth. Along the strike the ores pinch out in lens fashion. The longest lens in the district reaches 2,000 feet.

The relations of the ores to the adjacent rocks are complicated by faulting of block type, characteristic of the basin region. The main directions of the fault planes are a little west of north and north of east. The planes are vertical. The district lies about 15 miles west of the great Hurricane fault, marking off the high plateau region from the basin region to the west, where the displacement is down on the west side.

CONCLUSION.

The ores of the Hartville district of Wyoming seem to have certain features in common with Lake Superior ores, but much work remains to be done on them before their origin can be definitely stated. With this exception the iron ores of the western United States seen by the writer and other deposits of which he has seen reports occur along or near the contact of limestones with intrusive igneous masses, both acid and basic, often laccolitic in form, and are frequently associated also with surface eruptives. The ores are clearly replacements of limestone and to a minor extent vein fillings in the limestone or igneous rock. Their association with igneous rocks and frequent content of metamorphic minerals point clearly to their development and concentration under the influence of igneous rocks and in some cases to more than one concentration. The precise nature of the influence of the igneous rocks can not now be stated. They may have contributed hot waters bearing the iron ore; they may have contributed hot waters which have leached the ore from the intruded limestones; they may have contributed only heat necessary to make meteoric waters highly effective in concentration; or probably there was some combination of these factors.

The ores are predominantly magnetic, particularly in their upper portions. Locally, as in Utah, they grade down into hematite. The magnetite sometimes shows a thin surface alteration to limonite. In places the ore is largely limonite. The iron content locally runs up to 65 or 66 per cent, but the average is lower. A considerable proportion of the ores may average above 50 per cent. The phosphorus content is variable but usually high. The phosphorus often occurs in apatite in large crystals, making it possible to effect a rude separation of high phosphorus ores by hand sorting. A considerable proportion of the ores contain iron or copper sulphides or both to such an extent as to require roasting, though to this there are important exceptions.

The exposures are such that the horizontal dimensions of the ores may be ascertained. The vertical extent down the usually inclined contact surfaces has for the most part not been determined. Depths of more than 300 feet are known, and the geological structure makes greater depths probable. Neither is it known how rapidly the deposits narrow below. Until these facts are known, satisfactory estimates of tonnage can not be made. While no single western district has yet been shown to be comparable both in quantity and quality of ores with any one of the Lake Superior districts, it is still certain, from the facts now known, that the West will in the aggregate furnish a large supply of iron ore and that the expenditure of money for exploration and exploitation is warranted. This does not mean that all of the western iron ores may become immediately available, for the grade and quality of the ores, together with their distance from consuming centers, may make it necessary to hold them for many years.

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Birkinbine, J. American blast-furnace progress. In Mineral Resources U. S. for 1883-84, pp. 290-311. 1885.

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Boutwell, J. M. Iron ores in the Uinta Mountains, Utah. In Bulletin No. 225, pp. 221-228. 1904.

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COAL, LIGNITE, AND PEAT.

SURVEY WORK ON COAL DURING 1905.

By Marius R. Campbell.

GENERAL STATEMENT.

Coal is by far the most valuable mineral product of the United States. According to the statistics of production for 1904,[a] the four mineral products which stand highest in the list of values are as follows:

Mineral products of highest value in United States, 1904.

Coal	$444,816,288
Pig iron	233,025,000
Copper	105,629,845
Petroleum	101,170,466

Although in 1904 the production of coal was not quite equal to that of the preceding year, greater activity than in any previous year was manifest throughout the country in prospecting and developing new fields, and in efforts to determine better methods of utilization.

This was largely due to the establishment of a coal-testing plant at St. Louis, for which Congress appropriated the sum of $60,000. The interest taken in this work by coal operators, coal consumers, and the general public shows plainly that the people are keenly alive to anything that tends to the cheaper production and the better utilization of the fuels of the country.

The immediate results obtained during 1904 resulted in an appropriation for 1905 amounting to $202,000 for the continuation of the coal-testing work, and incidentally an increase was made in the appropriation for geologic work of the Survey, with the express provision that this increase should be used in the investigation of the fuel resources of the country.

In order to carry out the intention of Congress, a committee was appointed by the Director of the United States Geolological Survey to consider the best methods of exploiting the fuel resources of the country, and also methods for their better utilization. This committee consists of Dr. C. W. Hayes, geologist in charge of geology; Prof. J. A. Holmes, superintendent of the coal-testing plant; Mr. E. W. Parker, statistician, and Mr. M. R. Campbell, geologist. The members of this committee represent the varied phases of fuel work carried on by the Geological Survey, and their office is to advise and direct the work so as to cover the entire ground of geologic occurrence, utilization, and statistics of production.

GEOLOGIC WORK OF 1905.

The geologic work on the coals was placed under the general direction of the writer, and plans were at once made for the continuation of systematic detailed work in the old and well-known coal fields of the East and of special reconnaissance surveys in the western fields.

Pennsylvania.—In the eastern part of the United States geologic work was carried on as usual in the bituminous-coal field of Pennsylvania, in cooperation with the State authorities. Under this arrangement three 15-minute quadrangles, the Newcastle, Claysville, and Punxsutawney, covering a territory of about 750 square miles, were surveyed by George H. Ashley, who was assisted by Frank W. De Wolf, Frederick B. Peck, and M. J. Munn. In this region the coals are fairly well known and little information regarding new seams or new territory was developed. The object of the work was to determine the exact correlation of the various beds, the extent of the workable areas, and the geologic structure of the field. The latter was perhaps the most important object, since it not only has a direct bearing on the commercial development of the coal, but also on the accumulation of oil and gas, for which this region is particularly noted.

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[a] Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905, pp. 32, 33.

Kentucky.—In northeastern Kentucky the Kenova quadrangle was thoroughly investigated by W. C. Phalen, under the direction of G. H. Ashley, and the geologic relations of the coal beds were studied and mapped with considerable detail. The area examined is embraced in a 30-minute quadrangle, and covers approximately 950 square miles. In this region the main object of the work was to trace the outcrop and to correlate the various coal and clay beds, also to determine the thickness and extent of the workable parts of the beds and the general structure of the region.

Alabama.—In the southern Appalachians work of a similar detailed character was carried on by Charles Butts in the coal field near the city of Birmingham. In this region one 30-minute quadrangle in the vicinity of Birmingham was mapped, with the exception of the southeast corner. The territory examined lay mostly in the Big Warrior coal field, and the coal seams were very carefully examined and plotted on the map. Correlations were made and also accurate determinations of the extent and quality of the workable coal.

No work was done in the coal fields of the Mississippi Valley during the past year.

New Mexico-Colorado.—In the Rocky Mountain region a number of parties were at work making reconnaissance surveys of some of the little-known coal fields. In southern Colorado and northwestern New Mexico F. C. Schrader, assisted by M. K. Shaler, made a reconnaissance examination of about 2,050 square miles of territory. This party began operations at Durango, Colo., following the outcrop of the coal-bearing rocks to the east and south into the Mount Taylor region of New Mexico, and then swinging to the west and following in a general way the outcrop of the coal beds to Gallup, N. M., where there are several large mines in operation. For a number of years this field has been attracting attention and numerous railroad surveys have been made across it, presumably with the intention of developing its coal resources, but so far little practical development has occurred, except in the vicinity of Gallup, on the Santa Fe Railway, and around Durango and Monero, on the Denver and Rio Grande Railroad. During the past year a branch of the latter system has been built south from Durango to San Juan River, affording access to a very important part of this coal field. The work done by Schrader's party consisted in determining the areal distribution of the coals, correlating the beds worked at the various points, and determining the geologic horizons at which the coal occurs.

Colorado.—In the northwestern part of Colorado the Yampa or Routt County coal field has likewise attracted great attention for a number of years. Surveys have been made into the region by the Union Pacific Railroad and the Burlington System, but up to the present time no line has been constructed, and consequently the field has remained in an undeveloped condition. Recently public attention has been directed to this field through the building of the Denver, Northwestern and Pacific Railroad from Denver into Middle Park and its projection to the west down Yampa Valley. In order to meet the demand for reliable information regarding the coal of the Yampa field, a careful reconnaissance survey was made by N. M. Fenneman and H. S. Gale, assisted by R. C. Allen. A very detailed reconnaissance examination was made of a territory covering about 1,200 square miles along Yampa River, from a few miles below Steamboat Springs to the small village of Lay, near the center of the county. The feature of this field that has attracted the most attention is the occurrence of anthracite in the northern part, and some controversy has been carried on regarding the extent and value of these deposits. Considerable time was spent in an examination of this small anthracite area, in the hope that sufficient evidence might be obtained to determine its extent and commercial value, but owing to the broken condition of the coal-bearing rocks and the presence of considerable intrusive material, a great amount of surface wash, and a heavy covering of timber, it was almost impossible to determine the areal extent of metamorphism without thorough prospecting with the drill. There is no doubt that a good quality of anthracite occurs in this area, but until prospecting has been done there is great uncertainty regarding its geographic extent. The local character of the metamorphism of the coal makes it seem doubtful whether this area will ever be of very great commercial importance, but the field as a whole is undoubtedly very important, since there are a number of thick seams of good bituminous coal throughout its extent. This alone will amply repay development. Beyond the territory covered by this reconnaissance the coals are lignitic and of much poorer grade than they are in the territory surveyed.

North Dakota-Montana.—In view of the rather extraordinary results obtained at the coal-testing plant in making producer gas from brown lignite of North Dakota, it seemed desirable to determine more fully than heretofore the extent of such deposits in North Dakota and eastern Montana. For this purpose A. G. Leonard, assisted by Innis Ward and H. L. McDonald, made an examination of the country along Little Missouri River, from the crossing of the Northern Pacific Railway into South Dakota. They also examined the territory west of the Little Missouri between that and Yellowstone River and up the latter stream as far as Miles City, obtaining a large amount of information on the occurrence of workable beds of lignite and the general question of correlation with other parts of the field. In this region there are some thick beds of lignite, but they occur as lenticular masses, frequently having an area of only a few square miles and sometimes only a few acres. They are so common, however, that almost every section contains a bed of workable thickness. The work done in this region shows that similar conditions prevail over the western half of North Dakota and a large area in the southeast corner of Montana. At the present time there is little demand for these lignites, but with the simplification of the producer-gas apparatus and gas engine, the production of power from brown lignite will doubtless be attempted in many places. The tests[a] show that in the producer plant 3.47 pounds of Williston brown lignite were required to produce one electrical horsepower per hour, while in the steam plant it required 3.40 pounds of the best West Virginia steam coal to produce the same result. This shows that the brown lignite, though containing practically 40 per cent of water as it was fired in the producer, is almost as valuable for the production of power as the best West Virginia coal used under the steam boiler. When this method of production of power comes into common use doubtless it will bring new industries into the Dakota country and stimulate those that have already obtained a foothold. The lignite-bearing beds are not limited to the area just described, but extend indefinitely to the southwest and presumably are connected with the Sheridan field at the base of the Bighorn Mountains.

Wyoming.—The coal fields of Wyoming are among the more important ones of the Rocky Mountain States. Published data regarding some of them are available. Many of the others, though fairly well developed, have never been described. This is the case of the Hams Fork field, which lies in the southwestern part of the State. A survey of this interesting field was made during the past season by A. C. Veatch, assisted by Alfred R. Schultz. That part of the coal field covered by this survey has an area of 700 square miles, extending from a line somewhat north of the Oregon Short Line Railway in the vicinity of Kemmerer southward to the Utah line. Much data had already been obtained by the systematic prospecting of private parties in the region, and consequently the most important part of Veatch's work was the determination of the horizons of the various coal beds, the geologic structure, and the amount of unclaimed coal lands in this field. The report shows that it still contains a large acreage of Government land which can be entered as coal lands. A small oil field, known as the Spring Valley field, was also thoroughly examined and a considerable amount of new data on it was obtained.

Utah.—Geologic work was also carried on in the coal fields of Utah, which have long been recognized as among the most important in the West, but regarding which little published information is available. Considerable prospecting has been done, and large mines have been developed by the Utah Fuel Company at Castle Gate, Winter Quarters, Clear Creek, and Sunnyside.

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[a] Bull. U. S. Geol. Survey No. 261, 1905, pp. 82, 104.

The outcrop of the coal-bearing rocks shows continuously from Grand Junction, Colo., westward into Utah, in what is generally known as the Book Cliffs. This outcrop crosses the line of the Rio Grande Western Railway at Castle Gate, and at that point a large mine has been in operation for a number of years. West of Castle Gate the outcrop swings to the south along the eastern front of the Wasatch Plateau. Some development has taken place along this line to the south, and also to the north in an isolated field in the vicinity of Coalville, where considerable mining has been done.

During the past year J. A. Taff, assisted by C. D. Smith, made a reconnaissance of most of this territory, giving particular attention to the Book Cliffs field. This was done for the purpose of determining the number and extent of the workable beds, the quality of the coal, and the amount of coal land still unclaimed.

Other fields.—In addition to the work already mentioned, which was done expressly for the purpose of determining the extent of the fuel resources of the country, surveys were made of coals in other fields in the course of general geologic work. This was particularly the case in Wyoming, where C. A. Fisher obtained valuable information on the coals of the Bighorn basin; in New Mexico, where Willis T. Lee obtained data on the scattering coal fields of the central and southern part of the Territory, and in Utah, where G. B. Richardson obtained information on similar outlying fields in the central part of the State.

WORK OF THE FUEL-TESTING DIVISION.

The plan for the work of fuel testing was originally proposed by Prof. J. A. Holmes, chief of the mines and metallurgy department of the Louisiana Purchase Exposition, but the actual work of building up the plant and carrying on the tests for the first year was done by a committee. This committee was appointed by the Director of the Geological Survey and consisted of E. W. Parker, J. A. Holmes, and M. R. Campbell.

The conditions imposed by the act of Congress under which this work was done were that all the apparatus and material to be tested should be supplied free of charge to the Government, but even with this restriction and the small appropriation available a fairly efficient plant was established on the exposition grounds, with facilities for making chemical tests, washing tests, steaming tests, coking tests, briquetting tests, and producer-gas tests. Each of these lines of work was placed under a man who had made a specialty of work of this sort and was considered an expert. The plant was run continuously from about September 1, 1904, until January 1, 1905, and, after a shut down of a few months for alterations and repairs, was again put in operation in the spring of 1905. A preliminary statement of the first season's work was published several months ago as Bulletin No. 261 of the United States Geological Survey, and a more detailed report of that work has just been issued (Professional Paper No. 48).

Of the general results it is not necessary here to speak, but it seems desirable to call attention to the geologic bearing of the work. This may be divided into two parts—first, that which concerns the chemical composition of the coal; and second, the geographical distribution of the samples that were tested and their representative character.

CHEMICAL WORK.

The chemical work of the coal-testing plant was placed in charge of Prof. N. W. Lord, of the Ohio State University, Columbus, Ohio. Professor Lord has probably done more original work on the chemical composition of coals than any other man in the country, and the committee was extremely fortunate in being able to secure his services.

Sampling.—Samples were taken not only of the carload of coal when it reached St. Louis, but also of each individual lot as it was tested in the various departments. Two mine samples were also taken in the mine from which the carload was derived. This was done practically for all samples tested, and the result is a great mass of chemical data, showing the composition of the coal as it was sampled under various conditions. Proximate analyses were made of all of these samples and one ultimate analysis for each carload that was tested. These analyses provided material for study regarding, first, the different modes of sampling, and second, the chemical composition of the coal. It is the first instance in this country where a like number of ultimate analyses has been made. In fact, it is almost the only case in which such work has been done, especially on such a variety of coals, and the resulting data afford a most valuable basis for generalizations regarding the questions of coal composition and origin.

One result of this work was a paper by the writer on "The commercial value of coal-mine sampling,"[a] in which the data derived from the analyses just mentioned were compared and some very important conclusions were reached regarding the value of coal-mine sampling, especially with reference to the impurities, such as moisture, ash, and sulphur. It was found that the moisture in the car sample as it reached St. Louis in general was about the same as that originally contained in the coal of the coal bed, as shown by the analyses of the mine samples, which were sealed in air-tight galvanized-iron cans as soon as collected. The sulphur and ash, however, were different, and in the great majority of cases were much greater in commercial coal than in the mine samples. This simply means that in cutting the mine samples more care was exercised in excluding impurities than was done by the miners in the ordinary course of mining and loading coal.

The experience gained by this work seems to show that it is practically impossible to make the two kinds of samples agree. Hence coefficients of increase were determined for the 50 samples that were tested. In the case of sulphur the amount in the car samples in general was found to be 1.04 times the amount in the mine samples, and consequently to obtain the amount of sulphur in commercial coal the amount shown by the mine analysis should be multiplied by the coefficient 1.04. Similarly, the amount of ash in the car samples was found to be in general 1.3 times the amount shown in the mine samples. Therefore, to obtain the amount of ash in commercial coal the amount as shown by the analysis of the mine samples should be multiplied by 1.3. Heretofore there has been no such determination of the general relation between impurities in mine samples and in commercial coal, and analyses made of mine samples have generally been accepted as indicating the commercial value of any given coal. The results of this work show that such a determination is subject to very grave errors and that in general the ash and sulphur so determined should be multiplied by some such coefficients as those given above.

The general conclusions regarding the value of mine sampling were expressed as follows:

> As already stated, the rules and regulations adopted for mine sampling in this work aimed to secure samples which would correspond with the commercial product of the mine. The results show that this was not attained, and, furthermore, they show that a strong personal element necessarily comes in where certain things are left to the judgment of the sampler. Such a system may be fairly satisfactory where one man does all the sampling, but this is seldom possible. In the light of the results obtained in this work it seems to me that some arbitrary system that will eliminate the personal equation entirely is much better for general work, and therefore I recommend the following method of mine sampling:
>
> *Proposed method of mine sampling.*—1. Select a fresh face of coal, and clean it of all powder stains and other impurities.
>
> 2. Cut a channel perpendicularly across the face of the coal from roof to floor, with the exceptions noted in 3, of such a size as to yield at least 5 pounds of coal per foot of thickness of coal bed; that is, 5 pounds for a bed 1 foot thick, 10 pounds for a bed 2 feet thick, 20 pounds for a bed 4 feet thick, etc.
>
> 3. All material encountered in such a cut should be included in the sample, except partings or binders of more than 0.25 inch in thickness and except all lenses or concretions of sulphur or other impurities greater than 2 inches in maximum diameter and 0.5 inch in thickness.
>
> 4. The sample may be sent to the laboratory as it is cut, or it may at once be quartered down to about the size of a quart. If it is quartered down it should be pulverized to about three-eighths of an inch, and after thorough mixing it should be divided into quarters and opposite quarters rejected. The operation of mixing and quartering should be repeated until the desired size of sample is obtained. The operation of pulverizing and quartering should be done as rapidly as possible, so as to prevent a serious change in the moisture content, and then the sample should be sealed in either a glass jar or screw-top can, bound with tire tape, and sent to the laboratory for analysis.
>
> 5. The analysis of such a sample will show the grade of coal that may be obtained by careful mining and picking. In the majority of cases the sulphur and ash in the commerical output of the mine will

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[a] Trans. Am. Inst. Min. Eng., Washington meeting, May, 1905.

exceed the amount obtained from the sample, but this can be approximated by multiplying by certain coefficients. The coefficients determined in the work of the Geological Survey coal-testing plant last year will not be strictly applicable, since the sampling was not done under this system, but they are approximately the same and can be used until more accurate coefficients are determined. When sufficient data are at hand, it seems possible that specific coefficients may be determined for certain fields; that is, a coefficient for the Appalachian field, another coefficient for the Eastern Interior field, etc., and, finally, coefficients may be determined for local subdivisions of the larger fields or for certain beds of coal within those fields.

6. All descriptions of samples should state definitely how the samples were obtained, so that the reader may judge for himself the value of the results obtained; and when analyses are recalculated the coefficients of increase or decrease should be given, together with the authority for using this coefficient or the data on which it was determined.

CLASSIFICATION OF COALS.

The material made available by the work of the chemical laboratory led to another line of investigation—that is, the classification of coals. It has been generally agreed that proximate analyses afford no adequate basis for classification, though such a basis was proposed for the Pennsylvania coals many years ago. This, however, failed when it was applied to the lignites and low-grade bituminous coals.

As a result of the work of the coal-testing plant there became available fifty-six ultimate analyses of coals of all classes from brown lignite to anthracite, and this seemed to afford a favorable opportunity for an attempt at classification. After various trials the ratio of the carbon to the hydrogen seemed to present the best basis for a classification. This ratio runs from 26.7:1 in Pennsylvania anthracite to 9.4:1 in Texas brown lignite. With the data available it seems as if eleven groups may be recognized and separated by such a scheme of classification, as follows:

	Carbon-hydrogen ratio.
Groups A, B, and C.	
Graphite and anthracites (only one representative—Pennsylvania anthracite)	26.7
Group D.	
Semianthracite (not represented).	
Group E.	
Semibituminous (only one representative—highest class Arkansas coal)	20.7
Group F.	
Highest grade bituminous (best West Virginia and western Arkansas coals)	20 -17
Group G.	
Second-grade bituminous (second-class West Virginia, first-class Kentucky and Alabama coals)	17 -14.4
Group H.	
Third-grade bituminous (first-class Indian Territory, Kansas, Missouri, Iowa, and Illinois coals, and second-class Kentucky coals)	14.4-12.5
Group I.	
Lowest grade bituminous (includes majority of Iowa, Missouri, Illinois, and Indiana coals and some of the Wyoming and Montana coals)	12.5-11.2
Group J.	
Lignite (includes all lignites, both brown and black, that were tested)	11.2- 9.3
Group K.	
Peat	9.1

It is not expected by the writer that such a classification will ever be used in a commercial way. The trade names are now well established, and it is not feasible to attempt to replace them by such a scientific classification as the above. There is, however, demand for just such a classification to definitely fix the position and the relative value of a coal. For instance, if the ultimate analysis of a sample of coal shows a carbon-hydrogen ratio of 14:1, the place of the coal in the above scheme of classification is definitely fixed, and in a general way, impurities being excluded, the true value of the coal is also fixed. The groups proposed are put forward tentatively. From the analyses at hand they seem to represent all the grades of coal with which we are acquainted, but it is possible that with further data the limits of the groups may be changed to some extent. It is not probable, however, that this change will be serious, and it is hoped that the limiting figures as given will stand.

There is no sharp separation between the lignites and the lowest grade bituminous coals, but the above grouping probably represents the facts in the case. It is possible, however, that in future work the carbon-hydrogen ratio of some ligintes may be slightly higher than that of some bituminous coals. It is anticipated that there will always be a certain amount of merging along this line, but according to the present scheme the lignites fall within one general group, and hence it seems to apply to them as well as to the bituminous coals.

GEOGRAPHIC DISTRIBUTION OF SAMPLES.

The geologist is more or less interested in the question of what coals were tested and how well the samples represent the entire coal fields of the United States. It is difficult to show in a brief way these facts. The following table gives the distribution of the samples which had been tested up to January 1, 1906, and these are compared with the production of the various States for the year 1904 and also with the estimated area of the coal fields within the various States:

Comparative table showing production, number of tests, and area of coal fields of the various States.

State.	Production in 1904.	Number of mines sampled.	Estimated area of coal fields.
	Short tons.		*Sq. miles.*
Alabama	11,262,046	2	6,000
Arkansas	2,009,451	4	2,500
California	78,888	1	200
Colorado	6,658,355	1	7,000
Georgia	390,191	....	167
North Carolina			150
Idaho	3,480	....	....
Illinois	36,475,060	12	42,900
Indiana	10,934,379	11	6,500
Indian Territory	1,046,539	6	17,000
Iowa	6,519,933	5	10,000
Kansas	6,333,307	5	15,000
Kentucky	7,566,482	8	16,980
Maryland	4,813,622	....	450
Michigan	1,342,840	....	7,500
Missouri	4,168,308	4	14,000
Montana	1,358,919	1	32,000
New Mexico	1,452,325	2	2,700
North Dakota	266,128	3	28,620
Ohio	24,434,812	8	12,000
Oregon	111,540	....	300
Pennsylvania	97,952,267	8	12,200
Tennessee	4,782,211	....	4,400
Texas	1,195,944	2	35,000
Utah	1,493,027	....	2,500
Virginia	3,583,914	4	1,550
Washington	3,137,681	....	100
West Virginia	32,602,819	21	24,780
Wyoming	5,178,556	2	8,000

GENERAL RESULTS.

In addition to the above chemical and geologic data obtained by the coal-testing plant, it is desirable to call the attention of geologists to a new and improved method, developed during the course of this work, of utilizing coal in the production of power. This method consists of the conversion of the coal into producer gas and the use of this gas in an explosive gas engine. A brief preliminary statement of the results of these tests has been published in Bulletin No. 261, and full and complete descriptions are contained in the detailed report given in Professional Paper No. 48. Briefly, the results show great economy in the use of fuel for the production of power by this method. From the results so far obtained it seems probable that a gain in efficiency of 100 per cent may be expected over the ordinary practice with the steam engine. Although this gain applies to all grades of coal that were tested, the most striking results were obtained from the use of low-grade bituminous coals and lignites. The results were of such a character that they seemed to foretell a revolution in the mode of generating power in the near future, and if they are borne out in actual practice the low grade, dirty coals of Iowa and Missouri may be made to yield as valuable results as are at present obtained by the highest grade steam coals of West Virginia. This method also offers a great opportunity for the utilization of brown lignites of the northwest and of Texas, which, up to the present time, have been little used for such purposes.

Since the amount of ash has little effect in producer practice, unless clinkers are formed, it is probable that this method will afford a solution of the present great problem of the utilization of slack coals. This is one of the most serious questions that confront coal operators in this country, and the experiments so far conducted at St. Louis seem to show that waste products of this kind can be utilized to decided advantage in a producer plant.

THE WARRIOR COAL BASIN IN THE BIRMINGHAM QUADRANGLE, ALABAMA.

By Charles Butts.

INTRODUCTION.

The present paper is a preliminary and provisional report on a comparatively well-developed and well-known area. It is based on work done in the past field season, continuing the geologic survey of the Birmingham district. The region has been described by Mr. Henry McCalley, assistant State geologist, in the reports of the Alabama Geological Survey entitled "On the Warrior Coal Field" (1886) and "Report on the Warrior Coal Basin," with map (1900). Much help has been derived from these reports. The writer also acknowledges the receipt of valuable information from many individuals and mining companies operating in the region.

LOCATION.

The Birmingham quadrangle lies mainly to the north of Birmingham, Ala., and includes most of the city. It is a rectangular area of nearly 1,000 square miles, included within the parallels 33° 30′ and 34° and the meridians 86° 30′ and 87°. The northern boundary runs just north of Bremen and Cleveland, the eastern is a short distance east of Chepultepec and Henryellen, the southern passes through the southern part of Birmingham, and the western lies just west of Littleton and Bremen. The part of the area containing the coal beds described below is shown in the sketch map (Pl. V). On this map the areas underlain by workable coal beds are inclosed by the line representing the outcrop of the Black Creek seam. There are two principal areas—one in the southwestern part, wedge-shaped, broadest to the southwest, and extending northeastward to beyond the center of the quadrangle, and one in the northwest corner in the region of Arkadelphia Mountain. These will be designated as the southern and northern fields of the quadrangle. A few small outliers of coal occur near Arkadelphia Mountain and a considerable area in the vicinity of Creel. The combined areas equal about 250 square miles.

TOPOGRAPHY.

The surface of the coal-bearing territory is rough. Altitudes vary from 300 feet along the forks of Black Warrior River to 800 feet in the highest hills. Between the large streams are generally flat ridges, from which run off long, narrow spurs, separated by deep ravines. The larger valleys are narrow and crooked along a large part of their length, and bordered by bluffs or cliffs in many places.

Locust Fork of Black Warrior River drains the southern coal field and Mulberry Fork the northern. The minor drainage of the southern field is northwestward; that of the northern is southeastward. In the southern field, Village, Fivemile, Crooked, Cunningham, Turkey, and Gurley creeks are the most important streams; in the northern field Dorsey Creek is the only large stream.

Notwithstanding the roughness of the country it has been possible without great expense to reach by railroad many points at which the several seams of coal can be mined to advantage. There seem to be no serious obstacles to reaching all other points also at which mines can be advantageously located.

GEOLOGY.

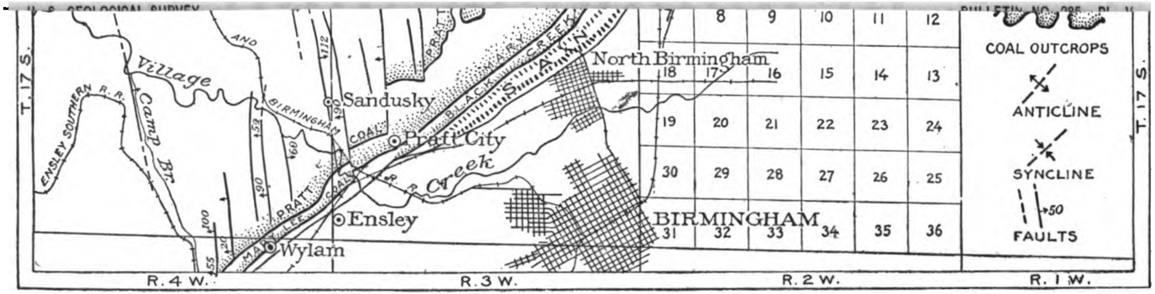
STRATIGRAPHY.

The coal-bearing rocks are of Pottsville age, like those of the New River and Kanawha coal fields of West Virginia and the lower rocks of the anthracite fields of Pennsylvania. They are sandstone and shale, with occasional thin limestones. The sandstone horizons are persistent, and some particular beds can be traced over large areas. The coal seams are generally closely associated with sandstone. The total thickness of rocks from the highest beds in the center of the syncline to the bottom of the Black Creek coal seam, as compiled from measurements in different parts of the basin, is 1,216 feet. Below is a generalized section:

Generalized section of coal-bearing rocks above the floor of the Black Creek coal.

	Thickness.	Depth.
Horizon of Gwin coal.	*Feet.*	*Feet.*
Shale	10	10
Sandstone	30	40
Shale	100	140
Coal (Cobb)	2	142
Shale	5	147
Sandstone	40	187
Shale and sandstone	260	447
Coal (Pratt)	3.5	450.5
Sandstone	35	485.5
Coal (Nickel Plate)	2.5	488
Sandstone	20	508
Shale	40	548
Coal (Curry)	1	549
Shale and sandstone	30	579
Coal (Gillespie)	.5	579.5
Shale and sandstone	313.5	893
Coal (Newcastle)	2	895
Shale	28	923
Coal (Mary Lee)	6	929
Shale or sandstone	60	989
Coal (Blue Creek)	2	991
Shale, sandstone, or conglomerate	50	1,041
Coal (Jagger)	3	1,044
Shale	10	1,054
Sandstone and conglomerate	25	1,079
Coal (Ream)	1	1,080
Sandstone	40	1,120
Shale	40	1,160
Coal (Lick Creek)	1	1,161
Shale and sandstone	40	1,181
Coal (Jefferson)	2.5	1,183.5
Shale and sandstone	30	1,213.5
Coal (Black Creek)	2.5	1,216
Shale and sandstone.		

In this section the details of thickness and character of the rocks are only an approximate average, but the intervals between the principal coal beds are fairly correct. The distance between the Cobb and Pratt coal beds was determined west of Wylam and Ensley, where the elevation of the Cobb coal was determined from its outcrop, and the elevation of the



MAP OF THE WARRIOR COAL BASIN, IN THE BIRMINGHAM QUADRANGLE, ALABAMA.

c
T
a
a
h
c
g

Pratt seam directly below is given in mine levels and bore holes. The average of two determinations of the interval by this means is 325 feet. The interval between the Pratt and Mary Lee seams, 473 feet, is obtained from the log of a bore hole in Sleepy Hollow near Blossburg. The interval between the Mary Lee and Jagger coals is compiled from observations made west of Morris, and is about right. The section between the Jagger and Black Creek coals was measured in a mine shaft at Kimberly

STRUCTURE.

To the southeast of the southern field a great thrust fault extends from Birmingham to Mount Pinson. The fault approaches nearest the coal measures from Pratt City to Wylam. Northeastward it diverges more and more to Mount Pinson. The rocks bounding the fault on the northwest are vertical or overturned to the west, with a southeasterly dip. West of the vertical zone the northwesterly dip decreases, so that in a distance of from 1 to 2 miles the rocks dip only 10° or 15° to the northwest or are nearly flat. Along the western edge of the field the rocks dip at a small angle to the southeast. In the southern field, as a whole, the rocks dip, in general, from the margin toward a line following Black Warrior River through Macknally Ford and extending southwestward to Republic, beyond which the rocks are so nearly horizontal and so much faulted that it would be difficult, with the data now at hand, to locate the axial line. The axis of the syncline pitches regularly to the southwest. The elevation of the Black Creek coal is about 500 feet above the sea on the axis near Dean Ford and about 450 feet below sea level south of Republic, making the total descent of the seam between the two points 950 feet. The basin is therefore spoon-shaped. There is a low anticline running about midway between the main synclinal axis and Coaldale and Kimberly, and a low syncline near Brookside and Pinkney. The southern field is also much faulted, especially along the southeastern margin. These faults are abundant from Wylam to Clift, on the Northern Alabama Railway, or at least are much better known in that area, where they have been encountered in mining. There are faults also in the vicinity of Warrior and Coaldale. A fault passes just west of Indio and another was encountered in mining the Black Creek seam just east of Newcastle. The position of these faults is shown on the sketch map (Pl. V). The course of nearly all of the faults is N. 10° to 20° W. The displacement varies from 10 to 112 feet. The fault planes are nearly vertical, generally making an angle of 70° to 80° with the horizon. The coal is reported undisturbed and workable right up to the faults. Between Newcastle and Cunningham station is a disturbed area, the rocks exposed in the railroad cuts midway between the two places being greatly distorted. This disturbance is spoken of as a fault, but it appears to be an overturned anticline. The disturbed zone extends northeastward parallel to Sand Mountain and about 1 mile northwest thereof to Turkey Creek, though the disturbance is not so great at all points along this course as it is between Newcastle and Cunningham station.

The structure of the northern field is very simple. A synclinal axis pitching to the southwest appears to pass through Arkadelphia and cross the western margin of the quadrangle near Locust Fork of Black Warrior River. The strata of Arkadelphia Mountain dip southeastward and those of the area north of Creel dip northeastward to the axis. The dip is low in both areas, probably not exceeding 100 feet to the mile.

COALS.

GENERAL STATEMENT.

The coal seams of the Warrior basin were divided by Henry McCalley[a] into six groups, which, in descending order, are as follows: Brookwood, Gwin, Cobb, Pratt, Mary Lee, and Black Creek. Each group consists of two or more seams, separated by from 20 to 60 feet of shale or sandstone, or both, though sandstone generally predominates. The intervals between groups vary from 100 to 300 feet. The rock filling these intervals is usually shale.

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[a] Report on the Warrior coal basin.

BROOKWOOD AND GWIN GROUPS.

The Brookwood and Gwin groups are so high in the series that they do not occur in the Birmingham quadrangle, though the sandstone ridge south of Camp Branch reaches up to the horizon of the Gwin seam. No traces of that seam were seen, and if it is present it occurs only in small areas under thin cover in the southwest corner of the quadrangle, and is of no commercial importance.

COBB GROUP.

The Cobb group of coals occurs only in the southwest corner of the quadrangle and is not economically important, so will not be discussed here.

PRATT GROUP.

The Pratt group includes the Pratt, Nickel Plate, Curry, and Gillespie seams. Only the Pratt and Nickel Plate are important. Generally the Curry and Gillespie seams are not minable.

Pratt seam.—This has been the most important mining seam in the quadrangle, but its area is less than that of any of the other prominent seams, as shown by its outcrop on the map (Pl. V). Its thickness, character, and quality are fairly constant. In an area lying, in a general way, south of Fivemile Creek, and including Republic, Pinkney, and Blossburg, the seam has two or three partings. The following sections are the average of three measurements each of the seam in this area. Section No. 1 represents its condition in that part of the area in which there are three partings and section No. 2 where there are only two partings.

Average sections of Pratt seam in the Republic-Blossburg region.

No. 1.

	Inches.
Coal	5¼
Parting	¾
Coal	4
Parting	¾
Coal	11½
Parting	⅝
Coal	15½
	38⅝

No. 2.

	Inches.
Coal	6
Parting	2½
Coal	26¾
Parting	1¼
Coal	2¼
	38¾

Outside of the area discribed above, on the northern and eastern margins of the field, the Pratt seam has almost universally one parting, as shown in the following section, which is the average of 26 measurements:

Average section of Pratt seam around northern and eastern margins of field.

	Inches.
Coal	5¼
Parting	2½
Coal	34
	41¾

The above sections indicate a thinning as well as a deterioration in the character of the seam to the northwest. The Pratt seam has been more extensively mined than any other in this part of the Warrior basin and is the standard coking and steam coal of the Birmingham district. Its chemical composition is shown by analyses Nos. 1 to 10 in the table on page 221.

Nickel Plate seam.—The Nickel Plate of this region is the same as the American seam of McCalley's report.[a] Nickel Plate is the name universally used by the miners of the region and for that reason is adopted here. It is known to be a workable seam in a large part of the territory between its northwestern outcrop and a line roughly drawn from Jugtown to Adamsville. The Nickel Plate is 35 to 40 feet below the Pratt seam. The interval between them is usually filled by sandstone, which in most of the region closely overlies the lower seam. So far as known, the Nickel Plate seam is greatly broken by partings, and probably it is of little value along its southeastern outcrop. The seam, where workable, is uniformly about 32 inches thick and is generally divided into two nearly equal benches by a 2-inch parting in the middle, as shown by the following section:

Average of nine measurements of the Nickel Plate seam.

	Inches.
Coal	18¼
Parting	1⅝
Coal	12¾
	32⅝

The upper bench is the purer coal, the lower bench carrying a larger proportion of ash and sulphur, as shown in analyses Nos. 11 to 14, on page 221.

MARY LEE GROUP.

This group consists of the Newcastle, Mary Lee, Blue Creek, Jagger, and Ream seams. With the probable exception of the Ream seam, these are all workable to a greater or less extent in the quadrangle.

Newcastle seam.—The Newcastle seam appears to be of minable dimensions only at Newcastle, where it exhibits the following average section:

Average of two measurements of Newcastle seam at Newcastle.

	Inches.
Coal	10
Parting	1¼
Coal	9½
Parting	2½
Coal	3½
Parting	3½
Coal (with parting 0 to 2 inches)	25
	55¼

The seam as exhibited in this section is certainly known only over a small area west of Newcastle. A seam of similar character occurring at about the same horizon is known to the northeast and north of Newcastle as far as Morris. This may be either Newcastle or Mary Lee, or a seam formed by the union of both. It is regarded here as the Mary Lee, since there appears to be one seam of the group wanting in the region. Southwest of Morris the Newcastle seam is thin, so far as known, and from 5 to 40 feet above the Mary Lee seam.

Mary Lee seam.—The Mary Lee seam is of great importance, since on account of its extent, thickness, and composition it is destined to become the main source of supply of coking coal in the region when the Pratt seam is exhausted. It is best known at Littleton and Sayre, on its northwestern outcrop, and at Lewisburg and Sayreton, on its southeastern outcrop. The seam can be identified with certainty from Sayre to Crooked Creek. From the vicinity of Morris around the northeastern outcrop to Newcastle there is doubt whether the top seam of the Mary Lee group is Newcastle or Mary Lee. It is treated here as Mary Lee. The seam is not well known along its outcrop southwest of Sayreton.

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[a] Op. cit.

The Mary Lee is a thick but very dirty seam. The coal requires washing before it is made into coke. The following average sections from various points exhibit its general character:

Average section of Mary Lee seam at Littleton and Sayre.

	Inches.
Coal	12½
Parting	¾
Coal	7½
Clay	6⅞
Coal	17½
Parting	⅞
Coal	10½
Clay	18¾
Coal (one or more thin partings)	31
	106¼

The two thick clay partings are persistent features of the seam in this locality. They divide the coal into three thick benches, which are more or less broken by thin sporadic partings.

West of Morris, in the vicinity of Crooked Creek, the tripartite character of the seam is not quite so conspicuous, although it still persists, as shown in the section below:

Average section of Mary Lee seam near Morris and Crooked Creek.

	Inches.
Coal	4½
Parting	¾
Coal	1¾
Parting	1⅞
Coal	5½
Parting	0–1¼
Coal	¼
Parting	6⅛
Coal	9¼
Parting (usually absent)	0–11½
Coal	2⅞
	45⅝

The partings of 1⅞ and 6⅛ inches shown in this section appeared in every section from which the average was obtained, and are constant features in the locality. They are probably the same as the two thick partings farther west. Northeast of Morris are a few outliers of this seam. To the east, at Fedora, along Flat Creek, and thence southwestward, it shows at a number of points. The coal is very dirty and generally thinner than it is farther south. It is always overlain by shale and underlain by sandstone. It is probably of less value along this part of its outcrop than elsewhere in the quadrangle. At Lewisburg and Sayreton it is a thick but dirty seam, as shown in the following section:

Average section of Mary Lee coal seam at Lewisburg and Sayreton.

	Inches.
Coal	8
Parting	1½
Coal	4½
Parting	⅜
Coal	4½
Parting	1¼
Coal	3
Parting	3¾
Coal	12
Parting	8½
Coal	28¾
	76⅛

Farther southwest, in the SE. ¼ sec. 16, T. 17 S., R. 31 W., the following section was measured at an old mine in what appears to be the Mary Lee seam:

Section of coal bed in sec. 16, T. 17 S., R. 31 W.

Shale.	Inches.
Coal	24
Parting	2
Coal	17
Parting	2
Coal	5
	50

A seam outcropping in the road to Republic, about one-fourth mile north of its intersection with the Pratt City-Birmingham road, is probably Mary Lee. The only other point at which coal was seen that is possibly an outcrop of this seam is in Wylam, near the siding to Pratt No. 5 mine and about midway between the mine and the post-office. At this point a vertical outcrop shows the following section:

Section of coal bed in Wylam.

	Inches.
Coal	14
Clay	2
Coal	4
Shale	48
Coal	3
Shale	3
Coal	8
	82

The position of this outcrop with regard to that of the Pratt seam, together with the dip of the strata, suggests that the coal is Mary Lee, though it may be some other seam of the Mary Lee group. On account of the weathering and crushing which the coal has undergone, the above section probably does not correctly represent its character in this locality.

Diamond-drill holes in the center of the basin show the Mary Lee coal to be of good thickness It probably is a minable seam throughout. Analyses Nos. 15–20 of the table on page 221 show the composition of the coal. It is coked and also used as a steam coal.

Blue Creek seam.—So far as known, the Blue Creek coal seam is of value only in the northeast end of the southern field, west, north, and east of Morris. The seam is of good thickness in this region, but, like the other seams of the Mary Lee group, it is very dirty, as shown by the following average of six sections measured at different points:

Average section of Blue Creek coal seam in the vicinity of Morris.

	Inches.
Coal	7
Clay	3
Coal	8½
Parting	0–1
Coal	8
Parting	0–3⅛
Coal	7¾
	38⅜

The partings are so distributed that generally there is no clean bench of coal over 14 inches thick. In only one section is there a clean bench 18 inches thick. In sec. 27, T. 15 S., R. 2 W., the Blue Creek seam reaches a great thickness, but is so full of partings as to be nearly worthless. Below is the section at this point:

Section of Blue Creek coal seam in sec. 27, T. *15 S., R. 2 W.*

	Inches.	
Shale.		
Coal	13½	69½-80½
Bone	4½	
Coal	5	
Bone	2	
Coal	4½	
Bone	½	
Coal	4	
Shale	3	
Coal	2½	
Clay	0-7	
Coal	2-6	
Clay	0-9	
Dirty coal (three-fourths inch thin partings)	19	
Shale	30	
Coal and clay	7	25¼
Coal	1	
Parting	¼	
Coal	17	
Clay	12	

There is no evidence that the seam as developed at this point is of considerable extent in the locality.

The seam is probably not known southwestward of the point described above to beyond Newcastle, but on the Louisville and Nashville Railroad, about one-fourth mile north of the junction of the Northern Alabama Railway, a seam is exposed which is probably Blue Creek. Below is the section:

Section of Blue Creek coal seam on Louisville and Nashville Railroad, one-fourth mile north of junction of Northern Alabama Railway.

	Inches.
Coal	6
Clay	3
Coal	1
Clay	12
Shale	60
Coal	12
Clay	12
	106

Farther south little or nothing is known of this seam and it is probably of no value along the outcrop.

Jagger seam.—The Jagger is a minable seam on Trouble Creek, along the river to the north of this creek, and perhaps along the river southwest of these localities. On Trouble Creek the top of the seam was seen in old pits and 2½ to 3½ feet of coal were reported by a man who had helped open the pits. On the south bluff of the river one-fourth mile west of the mouth of Whites Creek the following section was measured:

Section of Jagger coal seam one-fourth mile west of mouth of Whites Creek.

	Inches.
Coal	15
Bone and clay	15
Coal	15
Bone	2
Sandstone.	
	47

On the head of Whites Creek it is thin and lies under a coarse sandstone. Around the northeast end of the field it is thin or very dirty, as at Kimberly and Seloca, where it is exposed in railroad cuts. It is everywhere worthless in this region.

BLACK CREEK GROUP.

This is the lowest group of workable coals in the quadrangle and it has the greatest extent. The outcrop of the Black Creek seam on the map (Pl. V) shows the areas underlain by workable coal in the Warrior Basin. The Black Creek group comprises the Lick Creek, Jefferson, and Black Creek seams. Only the Jefferson and Black Creek are workable coals.

Jefferson seam.—The Jefferson seam is reported 29 inches thick about 1 mile west of Littleton. Along the northwestern outcrop, from Littleton to Cane Creek near Watt, the Jefferson seam is not well known and appears to be of little value. In the Watt-Seloca-Kimberly region it is a minable seam running over 30 inches thick with partings. An average of seven sections in this region is given below:

Average section of Jefferson-coal seam in Watt-Kimberly region.

	Inches.
Coal	8⅝
Parting	1⅝
Coal	13¼
Parting	2
Coal	8
	33½

At Warrior the seam is split into two or three benches, separated by shale of varying thickness up to 20 feet. Along the outcrop north of Warrior the seam appears to have returned to normal conditions, as revealed in mining operations. Around the northeast end of the basin toward Lehigh and Selfville the Jefferson coal is thin and worthless. At Indio, however, it is of good thickness, but is broken into three benches by thick partings, as shown in the following section, which is the average of two measurements at the Indio shaft:

Average section of Jefferson coal seam at Indio.

	Inches.
Coal	11
Parting	3
Coal	15
Parting	15
Coal	5
	49

It is doubtful whether the Jefferson seam is of value anywhere along its southeastern outcrop from Lehigh to Wylam.

In the Creel area south of Locust Fork McCalley[a] gives measurements of this seam at three points, at two of which it is 30 inches thick and at the third 14 inches. It is not known in the Arkadelphia Mountain area.

As a whole this seam is variable in thickness and is workable only in certain regions, though its workable areas are of considerable extent.

Black Creek seam.—The Black Creek coal appears to be the most uniform in thickness and character of all the seams of the basin, except the Pratt. From Sayre to Warrior, including the mines at Kimberly, Watt, and Seloca, it runs about 2 feet of clear coal. Eight sections at points east of Warrior to Macknally Ford gave an average of 27⅜ inches of clear coal. At and south of Coaldale a parting occurs and the seam is slightly thicker. The following is an average of six sections in this locality:

Average section of Black Creek coal at Coaldale.

	Inches.
Coal	7⅝
Parting	4½
Coal	20¾
	32⅞

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[a] Op. cit.

The average in the Lehigh district is 30 inches of clear coal and at Bradford and Indio 41 inches of clear coal. According to McCalley it will run from 24 to 30 inches as far south as Newcastle, where it is reported 31 inches thick at an old mine A coal exposed in a railroad cut about one-half mile south of Hughes siding and identified by the writer as the Black creek seam has the following section:

Section of Black Creek coal one-half mile south of Hughes siding.

	Inches.
Sandstone.	
Shale.	
Coal	1
Clay	5½
Coal	3
Clay	3
Coal	4
Clay	1½
Coal	5
Clay	36
Coal	9
Shale	30
Coal	9
Clay	6
Shale.	
	113

If this is the Black Creek seam it has undergone a great change between this point and the Newcastle mine. At an exposure 2½ miles farther southwest the seam shows a similar condition, though there is a clear bench of coal 26½ inches thick. From Sayreton to the southern edge of the quadrangle the seam is practically unknown.

In the Creel area the coal runs 30 inches thick, generally of clean coal. In the Arkadelphia Mountain area the seam averages 26 inches of clear coal. It is immediately or closely overlain throughout this area by a thick, coarse sandstone and over large parts of the area it is underlain by sandstone.

The Black Creek coal is one of the most highly esteemed of the Alabama coals for steam and domestic purposes. On account of its great extent, its generally uniform thickness and character, and its excellent quality it must be reckoned as a very valuable resource. It will furnish future supplies of coal after the thicker seams of the basin have been exhausted.

MINING CONDITIONS.

Mining conditions are generally favorable. Except along the southeastern margin of the field from Bradford to Wylam the dip is low and even along this line only the lower coals dip more than 15° NW. as far south as Lewisburg. From Lewisburg southward the dip increases rapidly and at Wylam the seams of the Mary Lee group are vertical on the outcrop and the Pratt dips 30°-40° NW. The coal of the basin can mostly be mined out from the outcrop. The roof is generally firm. The coal separates readily from the roof and partings. The mines are but little affected by water and gas. The worst obstacles to mining so far encountered are the faults described on page 213. Many of these are now known and they can be taken into consideration in planning future operations in the lower seams, but undiscovered faults probably exist which will add an element of uncertainty to future calculations.

DEVELOPMENTS.

Operations in this part of the Warrior Basin have so far been confined to six seams, namely, the Pratt, Nickel Plate, Newcastle, Mary Lee, Jefferson, and Black Creek. The Pratt has been most largely mined and extensive tracts have been worked out. Of the other seams comparatively small areas only have been mined out.

At present there are 38 mines operating in the Pratt seam, 11 in the Nickel Plate, 1 in the Newcastle, 8 in the Mary Lee, 4 in the Jefferson, and 8 in the Black Creek. A few of these mines have been idle for a year or more on account of labor and other troubles.

CHARACTER AND COMPOSITION OF THE COAL.

The coals of the region are all bituminous. They average about 58 per cent fixed carbon, 27 per cent volatile hydrocarbons, 10 per cent ash, 2 per cent moisture, and 2 per cent sulphur. They are good fuel and steam coals and make excellent coke. The coking property of these coals gives them exceptional value. The coal from the Mary Lee seam everywhere and from the Pratt seam in localities is so full of impurities—clay, shale, and slate—that it is unfit for coking as it comes from the mines. These impurities are derived from the many partings that occur in the seams, as can be seen by a study of the detailed sections given in the preceding pages of this report. It is therefore necessary in the worst cases and desirable in others to remove these impurities by washing the slack and crushed coal in specially constructed washeries.

The composition of the Pratt, Nickel Plate, and Mary Lee seams is shown in the following table. These analyses were made under the supervision of Prof. N. W. Lord at the fuel-testing plant of the United States Geological Survey at St. Louis, Mo. The samples analyzed were taken in the following manner: From a freshly exposed face of coal a section was cut from top to bottom of the seam or bench sampled of sufficient width and depth to yield about 50 pounds of coal, rejecting, so far as possible, such impurities as are excluded from the coal in mining. By pulverizing and quartering down the sample was then reduced to convenient size and sealed up in a glass jar or galvanized-iron can. It was then soon sent to the coal-testing plant, where it was sealed in a glass jar until analyzed. In this way it is believed that samples were obtained that closely represent the quality of the coal that is put on the market.

Analyses of coal from Warrior field, Alabama.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Moisture	2.51	2.68	2.07	2.27	1.83	2.88	2.27	2.66	1.63	1.86
Volatile matter	27.10	25.17	26.80	27.00	29.28	29.56	26.86	29.93	30.81	28.52
Fixed carbon	59.96	61.82	61.28	57.70	57.53	56.91	55.82	59.04	64.03	64.73
Ash	10.43	10.33	9.85	13.03	11.36	10.65	15.05	8.37	3.53	4.89
Sulphur	1.68	1.86	2.13	1.79	4.24	2.04	2.45	1.71	.57	2.27
Calorific value determined:										
Calories	7,571					7,477				
British thermal units	13,628					13,459				
Air-drying loss, per cent	1.60	1.80	1.40	1.40	.90	1.60	1.10	1.60		

	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Moisture	3.35	3.10	2.86	1.76	3.14	3.40	2.89	3.35	2.49	2.16
Volatile matter	26.41	25.31	29.08	28.52	28.46	26.68	28.87	26.92	27.34	27.11
Fixed carbon	57.58	56.15	65.29	54.08	59.35	59.53	59.94	59.01	57.14	55.47
Ash	12.66	15.44	2.77	15.64	9.05	10.39	8.30	10.72	13.03	15.26
Sulphur	1.84	3.11	.95	4.05	1.05	.65	.63	.67	1.37	.93
Calorific value determined:										
Calories	7,247							7,369		
British thermal units	13,045							13,264		
Air-drying loss, per cent	2.10	1.90	1.30	1.00	1.60	2.00	1.60	2.20	1.20	1.30

1. Pratt seam, Warner drift, Republic, Ala. Republic Iron and Steel Company, owner. E. E. Somermeier, analyst. Chas. Butts, collector.

2. Pratt seam, Warner drift, twelfth left heading, room No. 19, Republic, Ala. Republic Iron and Steel Company, owner. E. E. Somermeier, analyst. Chas. Butts, collector.

3. Pratt seam, Tutweiler No. 4 drift, seventh left heading, 900 feet from main entry, Pinkney, Ala. Tutweiler Coal and Coke Company, owner. E. E. Somermeier, analyst. T. M. Campbell, collector.

4. Pratt seam, Tutweiler No. 4 drift, ninth right heading, 600 feet from main entry, Pinkney, Ala. Tutweiler Coal and Coke Company, owner. E. E. Somermeier, analyst. T. M. Campbell, collector.

5. Pratt seam, No. 16 Pratt mine, section 3, face heading mouth of fourth left entry, 1 mile west of Cardiff, Ala. Pratt Consolidated Coal and Coke Company, owner. E. E. Somermeier, analyst. E. M. Dawson, jr., collector.

6. Pratt seam, No. 16 Pratt mine, section 5, right heading entry No. 3, 1 mile west of Cardiff, Ala. Pratt Consolidated Coal and Coke Company, owner. E. E. Somermeier, analyst. E. M. Dawson, jr., collector.

7. Pratt seam, Kosmo mine, room No. 3, Mineral Springs, Ala. Pratt Consolidated Coal and Coke Company, owner. E. E. Somermeier, analyst. E. M. Dawson, jr., collector.

8. Pratt seam, Clift mine, Clift station, Ala. Pratt Consolidated Coal and Coke Company, owner. E. E. Somermeier, analyst. Chas. Butts, collector.

9. Pratt seam, No. 4 mine, sixth cross heading, room No. 1, Wylam, Ala. Tennessee Coal, Iron, and Railroad Company, owner. F. M. Stanton, analyst. E. M. Dawson, jr., collector.

10. Pratt seam, No. 4 mine, room No. 5, Kelso entry, Wylam, Ala. Tennessee Coal, Iron, and Railroad Company, owner. F. M. Stanton, analyst. E. M. Dawson, jr., collector.

11. Nickel Plate seam, Tutweiler No. 3 drift, fourth right heading, Pinkney, Ala. Tutweiler Coal and Coke Company, owners. E. E. Somermeier, analyst. T. M. Campbell, collector.

12. Nickel Plate seam. Tutweiler No. 3 drift, second left heading, Pinkney, Ala. Tutweiler Coal and Coke Company, owner. E. E. Somermeier, analyst. T. M. Campbell, collector.

13. Nickel Plate seam, No. 16 Pratt drift, upper bench, fifth right heading, 1 mile west of Cardiff, Ala. Pratt Consolidated Coal and Coke Company, owner. E. E. Somermeier, analyst. E. M. Dawson, jr., collector.

14. Nickel Plate seam, No. 16 Pratt drift, lower bench, fifth right heading, 1 mile west of Cardiff, Ala. Pratt Consolidated Coal and Coke Company, owner. E. E. Somermeier, analyst. E. M. Dawson, jr., collector.

15. Mary Lee seam, Thomas slope, ninth left cross heading, top bench, Littleton, Ala. Little Warrior Coal and Coke Company, owner. E. E. Somermeier, analyst. T. M. Campbell, collector.

16. Mary Lee seam, Thomas slope, ninth left cross heading, middle bench, Littleton, Ala. Little Warrior Coal and Coke Company, owner. E. E. Somermeier, analyst. T. M. Campbell, collector.

17. Mary Lee seam, Thomas slope, ninth left cross heading, bottom bench, Littleton, Ala. Little Warrior Coal and Coke Company, owner. E. E. Somermeier, analyst. T. M. Campbell, collector.

18. Mary Lee seam, Thomas slope, tenth left cross heading, whole seam, Littleton, Ala. Little Warrior Coal and Coke Company, owner. E. E. Somermeier, analyst. T. M. Campbell, collector.

19. Mary Lee seam, Lewisburg slope, bottom of main slope in manway, 60 feet from main slope, top bench, Lewisburg, Ala. Alabama Consolidated Coal and Iron Company, owner. F. M. Stanton, analyst. E. M. Dawson, jr., collector.

20. Mary Lee seam, Lewisburg slope, bottom of main slope in manway, 60 feet from main slope, bottom bench, Lewisburg, Ala. Alabama Consolidated Coal and Iron Company, owner. F. M. Stanton, analyst. E. M. Dawson, jr., collector.

COAL IN THE MOUNT DIABLO RANGE, MONTEREY COUNTY, CAL.

By RALPH ARNOLD.

Location and topography.—A deposit of coal [a] of commercial importance and also worthy of note because of its occurrence in such a comparatively recent formation as the Lower Miocene is found in Stone Canyon, near the middle of the Mount Diablo Range, Monterey County, Cal. The range in this region consists of a main divide, attaining an elevation of over 3,000 feet, and several less prominent parallel ridges, all trending in a general southeast-northwest direction. The coal outcrops about midway down the western flank of the main ridge. The locality is about 23 miles northeast of Bradley, and may be reached over wagon road from either Bradley, San Miguel, or Coalinga.

Geology and structure.—The formations involved in the geology of the range in the immediate vicinity of the coal deposit are the serpentine, chert, and other metamorphosed rocks of the Franciscan (pre-Cretaceous) complex, the Lower Miocene sandstone, and the basal sandstone and white shale of the Santa Margarita (Upper Miocene) formation. The Franciscan forms the core of the main ridge, outcropping intermittently along its top and also in a band along its western flank. The Lower Miocene sandstone, at the base of which is the coal bed, overlies the Franciscan unconformably and forms a steeply northeastward-dipping belt along the eastern side of the western band of Franciscan. A thickness of at least 500 feet of the Lower Miocene sandstone is exposed in the vicinity of Stone Canyon. About 35 feet above the top of the coal bed is a thin fossiliferous stratum in the sandstone, yielding the fauna which determines the age of the formation. The Santa Margarita beds, consisting of from 100 to 200 feet of coarse sandstone overlain by 1,000+ feet of thinly laminated hard white shale, rest unconformably upon the Lower Miocene and cover considerable portions of the main ridge. In the immediate vicinity of Stone Canyon the Santa Margarita forms a southeast-northwest syncline, which separates the Franciscan area on the top and northeastern flank of the main divide from the Franciscan and coal-bearing Lower Miocene outcrops on the southwestern flank.

The local structure, as shown by fig. 9, is essentially that of a syncline of the Santa Margarita sandstone and shale resting on a post-Monterey (Middle Miocene) erosion surface. The Lower Miocene formation, including the coal at its base, is separated from the Franciscan complex by an unconformity, and possibly also by a zone of faulting.

Coal bed.—As previously stated, the productive coal bed occurs at the base of and conformable with the lower Miocene sandstone. The bed averages between 14 and 16 feet in thickness, and, in the places where it has been exploited, has a dip of about 70° N. 40° E. At some places along the outcrop where apparently the creep of the rocks down the side hill has affected it, the dip is as low as 30° and the coal bed is pinched out to an exposure less than 4 feet in thickness. The bed is said to extend for at least 2½ miles along the strike, the exploited area, however, being only some 3,000 or 4,000 feet long. The roof is of sandstone, while the floor is clay, made up of decomposed serpentine and other Franciscan rocks. Whether or not this clay represents the residuum from pre-Miocene surface decomposition or is finely ground material along a fault zone, the writer is not prepared to state.

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[a] A brief description of this deposit and of the Stone Canyon coal mine is given in the Eighth Ann. Rept. Cal. State Mineralogist, 1888, pp. 403-404.

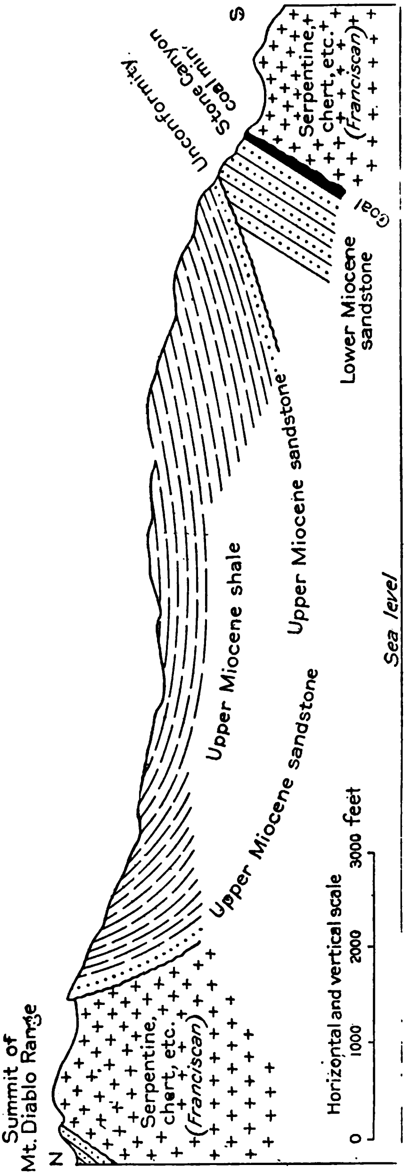

FIG. 9.—Theoretical section from the Stone Canyon coal mine, Monterey County, Cal., northward to the main ridge, showing relation of Upper Miocene beds to the coal-bearing formation.

Properties of the coal.[a]—The coal is hard and exhibits a clean black fracture. Although called a lignite, it appears to approach bituminous. It carries no iron pyrites, the large quantity of contained sulphur occurring principally, so it is said, in the form of calcium sulphate. The coal does not take fire spontaneously and is noncoking. Heating tests show its calorific power to be 13,000 British thermal units. The following analyses, taken from a mining engineer's report on the mine, are said to represent fair averages from different parts of the mine:

Analyses of coal from Stone Canyon mine.

Sample from—	Water.	Volatile carbon.	Fixed carbon.	Ash.	Sulphur.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Tunnel	6.13	50.08	36.39	7.40	4.65
Do.	6.14	48.57	38.84	6.51	4.82
Do.	5.50	50.34	37.61	6.55	5.09
Do.	7.12	49.15	34.88	8.93	4.74
Shaft..	4.80	51.40	34.21	10.59	6.41
Do.	4.42	46.30	30.54	18.71	5.79
Do.	3.82	53.28	38.35	4.55	4.88
Do.	2.99	53.38	38.28	5.38	5.40

Conclusions.—The coal appears to have been formed in a basin previous to the principal Miocene subsidence. The limits of this basin are unknown, although a deposit of coal found near La Panza, nearly 50 miles southeast, and occupying a similar stratigraphic position to that of the Stone Canyon bed offers evidence of rather widespread coal-forming conditions at the beginning of the Miocene.

Considerable prospecting has been carried on along the top of the range at the contact between the Santa Margarita sandstone and the Franciscan rocks, in an apparently analogous position stratigraphically to that in which the coal occurs on the west side of the syncline, a position in which, were the analogy true, coal would most likely be found. Paleontologic and structural evidence, gathered during a brief reconnaissance of this territory, appears, however, to indicate that this analogy is not true and that, in reality, the sandstones resting on the Franciscan along the top of the range lie stratigraphically unconformably above the coal-bearing sandstones, and are, therefore, not likely to contain coal. Fig. 9, illustrating the probable structural relations in the area under discussion, will indicate better than words the reasons for this last statement.

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[a] The writer is indebted to Mr. M. J. Horswell, assistant superintendent of the Stone Canyon coal mine, for a large part of the following information concerning the physical and chemical properties of the coal.

THE YAMPA COAL FIELD, ROUTT COUNTY, COLO.[a]

By N. M. FENNEMAN and HOYT S. GALE.

LOCATION.

The existence of important coal resources in northwestern Colorado has been known for many years. The region of greatest interest is in the eastern half of Routt County, lying in the upper valley of Yampa River. The area covered by this survey of the field is approximately 1,200 square miles and this is practically the extent of the Yampa coal field. It lies at the western foot of the Park Range of the Rocky Mountains. On the north are the high peaks and ridges of the Elkhead Mountains. On the south the field is interrupted by an east-west anticlinal fold through Axial Basin, supposed to the be eastward extension of the Uinta uplift, which merges into the White River Plateau. To the west and northwest the coal-bearing rocks extend to an undetermined distance, disappearing beneath formations of later age.

The coal field lies approximately midway between the Union Pacific Railroad on the north and the Denver and Rio Grande Railroad on the south. Steamboat Springs, the most prominent town of the district, is usually reached by stage from Wolcott, Colo. The field is also reached by stage from Middle Park and Rifle, Colo., and from Rawlins, Wyo. A number of regular stage lines run through the field.

The prospect of a railroad through the center of the area has in recent years stimulated exploration and careful study. It seems almost certain that with more adequate transportation facilities the Yampa coal field will become an important factor in the supply of the western market. The coals are for the most part a good grade of bituminous, and anthracite of good quality is known to exist within a certain limited area.

The field centers about a broad area of rolling country, of characteristically smooth slopes, although at places showing considerable relief. This is bounded by a sharply dissected rim of sandstone ridges rising to 1,200 or 1,500 feet above the drainage level. Yampa River cuts across the field in a westerly course, flowing through broad, open bottom lands where the course lies over the soft rocks of the prairie land and through canyons where it has cut across the sandstone ridges.

STRUCTURE.

This coal field as a whole is a well-defined structural unit. It is the extreme southeastern point of a huge synclinal basin of the coal-bearing rocks, the axis of which passes almost directly through the towns of Yampa and Hayden. Since the basin as a whole plunges to the northwest, the beds along the axis dip in that direction. Following this axis from the extreme point of the fold, one passes over successively higher and higher members of the coal-bearing series until in Twentymile Park the uppermost group of coal beds is entered. These in turn are overlain by dark clay shale distinct in character from the rocks of the coal-bearing formation.

The major syncline just described is interrupted by a number of cross folds or wrinkles. The most prominent of these minor folds is an anticline the axis of which follows the crests of the high ridges on the west side of Twentymile Park and crosses Yampa River at the mouth of Tow Canyon. On the north side of the river the axis bends a little west of north,

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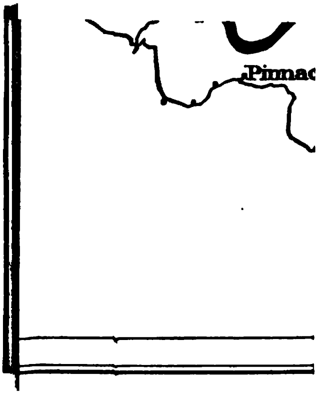
[a] This paper is a preliminary report, to be followed later by one giving fuller details and a more complete map.



LO.

ge seam, Yampa River.

Gulch.
nks, Williams Fork.
Bottom Ranch, Yampa River.

disappearing into an area of igneous eruptives in the direction of Wolf Mountain. This cross buckle of the strata lies approximately at right angles to the major axis and cuts off a structural basin on the southeast or Yampa end of the field. The center of this subordinate basin is marked by the open prairie land of Twentymile Park.

The rest of the field is a broadly opened syncline whose outer rim is made up of ridges formed by the massive sandstones of the coal-bearing series. Within this rim, which is a marked topographic feature, is a belt of open prairie and valley land eroded on the soft black shale that overlies the coal beds. These in turn are replaced in the center of the syncline north and west of the town of Hayden by beds of the overlying Laramie formation. The latter dip away to the northwest until they are covered by the overlying Tertiary rocks, which are supposed to cover all of the region along the Colorado and Wyoming line.

West of Twentymile Park the sandstone ridges swing to the west and form a low range of mountains on the north side of Williams Fork, called the Williams Fork Mountains. The sharply dissected southern slope of these mountains exposes the upturned edges of the whole coal series for over 20 miles. The coal beds dip to the north, passing under the barren shale which forms the valley of Yampa River.

The rim of sandstone ridges bounds the east side of Hayden Valley from near Twentymile Park to Wolf Mountain and Pilot Knob of the Anthracite Range. North of Pilot Knob the sandstones are much broken by intrusions of sheets and dikes of basaltic lava and consequently the rim of the basin is not well marked, but the coal beds have been traced in this direction as far as the flanks of Sand Mountain. All along this eastern rim of the field the rocks have a general westerly dip, also passing under the barren shale of the valley of Yampa River. In all probability the coals of the eastern rim extend beneath Hayden Valley and are continuous with the coal beds showing in the Williams Fork Mountains.

STRATIGRAPHY.

On the eastern side of the great syncline strata as old as Triassic lie tilted against the Archean core of the Park Range. To the west the Dakota, Benton, and Niobrara are crossed, each in its turn dipping under the next higher formation. Above these, at a distance of several miles from the Archean core, is a thick mass of coal-bearing strata. These rocks have been previously considered as of Laramie age, but fossils collected from them during the past season's work were sufficient to determine definitely that they belong to the Montana group of the Cretaceous. This group is the equivalent of the Pierre and Fox Hills formations of other fields, although this subdivision can not well be applied here.

Stratigraphic sections in different parts of the field do not agree in their minor details, but a few of the dominant members of the series are very persistent throughout the area and serve as useful horizon markers. The chief of these are some of the massive sandstone beds and the three groups of coal seams. The following is a generalized section, compiled from many such sections measured in various parts of the region:

Generalized section of the coal-bearing series.

	Feet.
Laramie:	
Alternating soft sandstone and shale, with frequent lignite seams	900+
Montana:	
(1) Dark-colored clay shale, with calcareous seams, estimated as	1,000-2,000
(2) Coal-bearing rocks, consisting of—	
(*a*) Alternating sandstone (at places massive) and shale containing the upper group of coals	400
(*b*) A persistent massive white sandstone	50- 150
(*c*) Alternating sandstone and shale beds containing in their lower half the middle group of coals	1,000
(*d*) A persistent massive white sandstone	50- 150
(*e*) Alternating sandstone and shale beds containing near their middle the lower group of coals	800
(*f*) Alternating sandstone and shale beds, massive sandstone predominating, with a few small coal seams near its base	800
(3) Dark-colored clay shale	1,000-1,500
	6,000-7,700

Each group of coal seams ranges through a vertical distance of from 200 to 400 feet and the several groups are separated by from 500 to 1,000 feet of barren shale and sandstone. The number and thickness of coal beds constituting each group vary from place to place. Usually there are in each group at least three seams of workable thickness and a number of smaller seams. Single beds of coal occur up to a thickness of about 20 feet.

At or near the base of each coal group are found conspicuous sandstone beds. These are characteristically massive and white and frequently more than 100 feet thick. While generally ridge or ledge makers, the exposed surfaces readily weather to a friable condition. The broad exposures are frequently marked by cracks making polygonal figures a foot or more in diameter. Great concretions and stains of iron oxide are also common.

Below the three coal groups is a great series of very massive sandstone beds, sometimes designated as the "barren sandstones." Where exposed these are usually prominent as a series of hogbacks. As stated in the generalized section, a few small seams of coal are found low down in this series.

The Laramie, overlying the Montana, is composed of alternating sandstones and clay shales. At least 900 feet of such sediments are embraced in the steep scarp on the north bank of Yampa River at Hayden. In this bluff indications of lignite were found at twenty horizons, distributed somewhat regularly throughout the upper two-thirds of this thickness.

COAL.

For convenience in describing the various mines and outcrops the field has been divided into four main structural districts, as follows: (1) Twentymile basin, including the extreme southeast point of the syncline and bounded on the northwest by the cross anticlinal fold mentioned on a previous page; (2) Williams Fork Mountains, including the southern rim of the main basin west of the cross anticline and Twentymile Park, and the outcrops in Yampa Valley in the vicinity of Craig; (3) Wolf Creek and Anthracite Range, including the coal beds exposed on the eastern rim of the main basin from Yampa River as far north as the coals have been traced; (4) Lower Elkhead and Fortification creeks, including the lignite coals of the Laramie formation and lying in the structural center of the main basin of the field.

TWENTYMILE BASIN.

This structural basin includes the coal beds exposed on Oak, Trout, Middle, and Fish creeks and a small area on and near Yampa River about 2 miles west of Pool post-office. In this basin all the coal-bearing rocks dip in general toward its center, which is Twentymile Park, and thus they form a single structural basin. Each creek valley, however, forms a distinct district or commercial unit, for the developments in a single valley are in the main subject to similar conditions of accessibility and convenience to market, and these conditions are usually different from those of adjacent valleys in the same structural basin.

Oak Creek district.—Coal seams outcrop along the upper valley of Oak Creek for a distance of at least 9 miles. The valley of this creek practically outlines the extreme southeastern limit of the coal field. Coal beds occur in the high bluff north of Pinnacle post-office and probably they are continuous along the bluff on the north side of the creek as far as the Yampa and Eddy road. By the side of this road in a small tributary valley of Oak Creek there are a number of openings, which are generally known as the James mine (W on map, Pl. VI). There is some doubt as to the position of the beds opened in these mines, but they probably belong to the lower coal group. Openings have been made on three seams, separated by intervals of about 35 feet each. The coal dips about 10° NW. The principal mine is on the uppermost bed that is exposed. An entry has been driven in on the coal bed for some distance, and considerable coal has been mined for local use and to supply the growing town of Yampa. The mine was not in operation at the time it was visited, and a complete section could not be obtained. The exposed part of the bed is as follows:

Section of upper coal bed at James mine.

	Ft.	In.
Shale, dark.		
Coal		5
Clay, white		1
Coal (base not reached)	7+	
	7	6+

The next or middle coal seam was not accessible, and consequently was not measured. An incomplete section of the lower seam, as shown in the principal opening at this point, is as follows:

Section of lower coal bed at James mine.

	Ft.	In.
Coal, good, bright	3	2
Coal, dirty		3
Coal, flaky		10
Clay, white		½
Coal, good, bright (base not reached)	1	1½+
	5	5+

Farther down the creek a coal bed also belonging to the lower coal group is opened by the side of the road leading from Yampa to Eddy post-office. This opening is generally known in the region as the Shuster mine (A). An entry has been driven in on the coal bed for several hundred feet and a large amount of coal has been taken out for local use. At the time of the visit the coal was being hauled from this point to Steamboat Springs for use in the electric-light plant. The section of the coal bed in this mine is as follows:

Section of coal bed in Shuster mine.

	Ft.	In.
Coal	3	3
Shale, carbonaceous	1	6
Coal	1	11
Clay		1
Coal	4	9½
	11	6½

The seam dips in general to the northwest, at an angle of about 20°. A sample was taken at this mine for chemical analysis. It was obtained by making a cut across the face of the coal in one of the rooms of the mine, and it includes all of the two lower benches of the coal, exclusive of the clay parting.

Analysis of coal (sample A) from Shuster mine.[a]

[F. M. Stanton, analyst.]

Moisture	8.85
Volatile matter	36.06
Fixed carbon	50.19
Ash	4.90
	100.00
Sulphur	1.51
Loss of moisture on air drying	2.30

Below the Shuster mine the coal beds of the lower group have been opened in a number of places along Oak Creek, but the most important development has been at the point where the Oak Creek leaves the coal field and turns east toward Yampa River. Here a great deal of mining has been done in the past. The only mine now operating at this point is one on the south side of the creek, owned and operated by the Steamboat Springs Electric Company (X). The coal is considerably crushed. At the time this mine was visited it was impossible to secure a detailed measurement, but the coal bed appears to be the same as that operated at the Shuster mine and to have a similar thickness. Six coal seams show on the north side of the creek in a section about 230 feet thick. The sandstone and coal beds dip about 45° W.

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[a] Samples for analysis were taken in a uniform manner throughout the field. A face of the coal seam was first cut down so as to expose fresh coal. A channel was then cut across the whole seam, only that part which would be saved in actual mining or such as appeared to be good merchantable coal being saved for the sample, and all bony seams and partings being thrown out. This large sample was pulverized and quartered down to convenient size at the mine and there sealed in an air-tight galvanized-iron can. The analyses were made under the supervision of Prof. N. W. Lord, of the Ohio State University, at the laboratory of the United States Geological Survey coal-testing plant, St. Louis, Mo.

The middle coal group outcrops near the summit of the bluff on the west side of Oak Creek, about 500 feet above the Shuster mine. The outcrops appears to be continuous from this point to Eddy post-office, but only prospect pits were found, and these seemed to indicate that the coal beds are not so valuable as are those of the lower group in this locality.

Trout Creek Canyon district.—A number of coal seams are exposed on upper Trout Creek near the mouth of the canyon, about 6 miles above Eddy post-office. The seams are opened near the road that crosses from Oak Creek, and they probably occur in the middle coal group. About three-fourths of a mile above this point another group of coal seams has been prospected. These probably belong to the lower group, which is thought to follow down Trout Creek on the crests of the ridges in approximately horizontal position from Pinnacle post-office to near the mouth of Trout Creek Canyon, where this coal group suddenly dips below water level. On one of these seams of the lower group an entry has been driven in 40 feet, showing 6 feet 3 inches of coal (B). The coal was slightly weathered, but a sample cut across the face of the seam gave the following analysis:

Analysis of lower coal (sample B) in Trout Creek Canyon.

[F. M. Stanton, analyst.]

Moisture	8.59
Volatile matter	33.85
Fixed carbon	47.30
Ash	10.26
	100.00
Sulphur	1.50
Loss of moisture on air drying	4.10

Eddy district.—The middle and lower coal groups cross Trout Creek in the vicinity of Eddy post-office, and mines and prospects show that both groups carry workable coals. A coal bed of the lower group is opened at the Jones mine, on the north side of Trout Creek, 1¼ miles below Eddy. The coal is nearly horizontal and shows the following section:

Section of coal bed at Jones mine.

	Ft.	In.
Coal	1+	
Clay		3
Coal	6+	
	7	3+

This coal group contains a number of thick beds, as shown by the section on the county road which crosses Trout Creek 2 miles below Eddy.

The middle group of coals has been opened on the Hutchinson property on Middle Creek (C), just above the crossing of the public road west of Eddy. The principal seams shows a thickness of 9 feet 6 inches of clear coal in the mine near Mrs. Hutchinson's house. A sample for analysis was taken at a new opening a few rods down the creek. This sample was obtained by making a cut across the lower part of the seam and represents a thickness of 5 feet of coal. The analysis is as follows:

Analysis of coal (sample C) from Hutchinson mine.

[F. M. Stanton, analyst.]

Moisture	12.50
Volatile matter	35.15
Fixed carbon	46.91
Ash	5.44
	100.00
Sulphur	.42
Loss of moisture on air drying	6.20

Another seam, 25 feet below the Hutchinson seam, has been opened a little farther down the creek, and to judge from the appearance of the dump heap, considerable coal has been taken from it. This bed shows a thickness of 6 feet 2 inches of clear coal. There are many other openings and prospects in this vicinity, but those given are representative of the larger seams.

Pool district.—At the mouth of Trout Creek Twenty-mile Basin extends to the north in the form of a narrow syncline and the coals of the middle and lower groups cross Yampa River. The situation will probably be best understood by reference to the map. Seams of both groups have been opened in this district. A lower seam of the middle group is opened at the McCroskey mine (D), on the north side of the river, a little less than 2 miles west of Pool post-office. At the time of visit this was the only mine being worked in the district. The coal is used for domestic purposes and is hauled as far as Steamboat Springs. The mine is driven in 400 feet and the following measurements were made:

Section of coal bed at McCroskey mine, on Yampa River.

	Ft.	In.
Sandstone roof.		
Bony coal	2 to 3	6
Coal, good	4	8
Coal, bony		6
Clay		3½
Coal, good	3	11
Coal, bony	1	
Sandstone floor.		
	10	6½

The following analysis was made from a sample representing all the good coal of this seam:

Analysis of coal (sample D) from the McCroskey mine.

[F. M. Stanton, analyst.]

Moisture	12.03
Volatile matter	34.51
Fixed carbon	42.79
Ash	10.67
	100.00
Sulphur	.47
Loss of moisture on air drying	4.40

This coal is one of several seams of this group showing in the face of the hill just north of the road. The amount of available coal at this point is, however, limited by the sharp tilting up of the point of the syncline a short distance north of this mine.

The lower coal group is well shown in the tilted sandstones along the stage road just east of Tow Canyon. Several of the seams have been burned in outcrop.

Coals of both the middle and lower groups have been opened south of the river. A seam of the lower group is opened at the old Brooks mine, situated in a gulch that opens into Trout Creek from the southwest near its junction with Yampa River. This seam is slightly over 5 feet thick and shows a face of solid, bright coal lying between massive beds of white sandstone. The middle group is developed in an old opening known as the Hitchins mine (Y), one-half mile southwest of the Brooks mine, in the same gulch and about 250 feet above the creek valley. This is a seam 10 or 11 feet thick. When visited the entrance was locked and the roof in bad condition.

A small structural basin of coals of the lower group lies on the summits of the ridges a few miles northwest of Pool post-office. These coals have been prospected by drifts in a number of places and are reported to be of workable thickness, but the prospects were not visited. The basin is a comparatively small one.

The western side of Twentymile Park is bounded by ridges of steeply upturned strata. Fish Creek cuts through this wall in a sharp canyon a short distance below Dunkley post-office. In this canyon the section of nearly the whole coal-bearing series is well exposed within a short distance. Seams of the lower and middle groups have been worked for local use. An old entry on a seam of the middle group measured 12 feet, more or less, of coal, overlying 8 feet of thin-bedded sandstone and shale. Under this is another seam of coal 3 feet thick. The dip is 56° E.

The coals of the upper group are exposed in many places in Twentymile Park. The representation on the map of the outcrop of this coal group is only approximate, for these coals lie above the more massive beds of sandstones of the coal-bearing series and are themselves covered by beds of soft and easily eroded shale. As both the upper coals and the overlying shale in large part occupy an approximately horizontal position, slight undulations of these beds may bring these coals to outcrop almost anywhere in the shale valleys and, on the other hand, may also carry the same coal seams to a considerable depth under the shale cover, without necessarily showing in the sagebrush prairie any surface indication of this structure. This is true of the upper coal group throughout the field, with the exception of the few districts in which the coals are tilted at such high angles as to make their outcrop a fairly definite line. The inferior quality of the coal in some of these seams that have been opened is probably due to lack of sufficient cover to have afforded protection from atmospheric agencies. The probability is, however, that a large proportion of this coal group lies sufficiently buried to have preserved the coal from such deterioration. The seams most deeply buried are not the ones most readily opened in prospecting.

WILLIAMS FORK MOUNTAINS.

This general district includes all the coals on the south side of the main field and west of Twentymile basin. The coals are exposed in outcrop on the crest and flanks of Williams Fork Mountains, which constitute the divide between Williams Fork and Yampa River. This definition of the district includes the Sage Creek coals, although these extend in outcrop, following the Sage Creek anticline, considerably north of the general trend of the coal groups of this district. From Sage Creek westward the outcrop of the three coal groups approximately parallels the crest of the Williams Fork divide, but is complicated by cross folds near the junction of Yampa River and Williams Fork. The cross folds are repeated for 8 or 10 miles to the west of the area shown in the map (Pl. VI) and finally disappear beneath the overlying strata in the vicinity of Lay post-office.

Sage Creek Canyon.—A little over 5 miles south of Hayden, Sage Creek emerges from a canyon eroded on the axis of a minor anticlinal fold. This fold, like that on the west of Twentymile Park, is not symmetrical, and has a steep dip on the east flank and a much lighter dip to the west. The three coal groups are exposed as indicated on the map. On the north slope a seam of the upper group has been opened and worked for the Hayden market. In the canyon two seams of the middle group have been opened by drifts and are now being worked for domestic use in and about Hayden. One of these seams (N) of the middle group measured 6 feet 10 inches of clear coal, and a sample for analysis representing the whole face was taken at the breast of a 300-foot drift. This seam dips 28° NE. The analysis is as follows:

Analysis of coal (Sample N) from the Barnes mine.

[F. M. Stanton, analyst.]

Moisture	11.23
Volatile matter	37.07
Fixed carbon	47.52
Ash	4.18
	100.00
Sulphur	1.60
Loss of moisture on air drying	4.20

About 75 feet below this seam, in the same group, is another seam (M) which measured 11 feet 5 inches. A sample of this coal, for analysis representative of the whole face, was also taken:

Analysis of 11-foot seam (Sample M) in Sage Canyon.

[F. M. Stanton, analyst.]

Moisture	11.03
Volatile matter	35.85
Fixed carbon	47.46
Ash	5.66
	100.00
Sulphur	.52
Loss of moisture on air drying	2.70

These openings are on the eastern or steep side of the anticline. About 1½ miles up the creek, on a small side gulch from the east, is a prospect on a seam of the lower group, showing about 10 feet of coal. This dips at an angle of 35° NE.

Dry Creek district.—The coals exposed along Dry Creek are of the upper group and lie against the west flank of the Sage Creek anticline. These coals have been opened at a number of places, and one entry (P) was being worked to supply the Hayden market at the time of visit. A sample of this seam, representing 7 feet 10 inches of solid coal that was being mined, was taken for analysis:

Analysis of coal (Sample P) from Dry Creek.

[F. M. Stanton, analyst.]

Moisture	15.74
Volatile matter	33.37
Fixed carbon	46.77
Ash	4.12
	100.00
Sulphur	.41
Loss of moisture on air drying	9.20

The whole section of the upper group as exposed in this vicinity was measured as follows:

Section of upper coal group on Dry Creek.

	Ft.	In.
Heavy white sandstone.		
Shale	3	
Coal	3	
Parting		1
Coal (mined)	7	10
Shale	12+	
Coal	2	
Bone		8
Coal	2	
Sandstone	4	
Shale, sandy	4	
Coal	5	3
	43	10

From the Dry Creek openings the road runs in a southerly directon across the Williams Fork divide and thence down Hayden Gulch. On the north side of the summit the road follows the outcrop of the upper coal group for several miles. These coals have been largely burned at the outcrop, as have many of the seams outcropping to the south and west of this district. In such cases the coals are marked by banks of reddened shale and sandstone and often by clinkers.

Williams Fork divide district.—On the south or Williams Fork side of the summit of the public road the trend of outcrop changes and all three coal groups turn across Hayden Gulch, as is represented on the map. About 1 mile from the mouth of this gulch openings have been made on seams of the lower group, which have been worked by the settlers from

Williams Fork. These workings are known as the Green and the Scott mines. The Scott mine exposes a seam of 9 feet 2 inches of good coal, overlain by 4 feet of shale. This was worked out in a large chamber, the roof of which was in a dangerous condition when visited. The Green seam (Q) was opened by an entry ending in a chamber and exposes a fine face of coal 10 feet thick. A sample from the Green seam, representative of the whole face as mined, shows the following analysis:

Analysis of coal (Sample Q) from the Green seam, Hayden Gulch.

[F. M. Stanton, analyst.]

Moisture	11.34
Volatile matter	34.49
Fixed carbon	49.57
Ash	4.60
	100.00
Sulphur	.50
Loss of moisture on air drying	3.40

From Hayden Gulch the outcrops of the lower and middle coal groups extend westward on the south slope of Williams Fork divide. The coals have been prospected at many points along this belt, but nowhere have they been opened to any considerable extent. These outcrops probably represent a large quantity of workable coal, having a very uniform light dip to the north. The outcrops are accessible in many gulches that extend back from Williams Fork.

In the vicinity of Hamilton post-office, on the south side of the river, some coals are exposed that are thought to belong to the lower group. These appear to be small outlying basins, a portion of the complication of folds lying between Williams Fork and Axial Basin. The Kellog coal bank, 5 miles south and a little east of Hamilton, was visited, as were also a number of prospects on thick seams in the same locality. The opening on the Kellog bank is a drift 200 feet in and shows 15 feet of solid coal, with coal roof and coal floor.

Lower Yampa district.—Near the junction of Williams Fork and Yampa River a large number of prospect pits and drifts and several banks to supply the local demand have been opened. These are on seams of all three coal groups. Among these a number of prospect drifts, locally known as the Greeley group, have been opened in the canyon of Yampa River. The openings on this property were in bad condition, owing to caving, but exposed a number of thick seams of coal, representative of the lower coal group at this point. Approximate measurements show one seam of 5 feet 8 inches of solid coal, another of 7 feet of coal with a 6-inch bony parting near the top, and still another seam 11 to 13 feet thick.

The Wise and Ratcliff banks (R), on Williams Fork, near its mouth, are on seams of the middle coal group. The Wise bank shows 8 feet of coal, with a shale roof, but the actual thickness of the seam may be somewhat greater. The Ratcliff bank, on a school section, was being worked under lease at the time of visit and most of the coal was being hauled to Craig. The opening was driven in 400 feet, and measurements of the seam showed 10 feet 7 inches of coal without partings, of which, however, the lower 16 inches were not mined. The mine has been worked in large rooms and the roof has caved badly in places. It is timbered with long poles set about 3 feet apart and is fitted with a 1-ton car and a small wooden frame tipple. A 4-foot seam is reported, lying about 50 feet below this seam, and both appear to overlie stratigraphically the seam of the Wise bank. The upper coal group is opened at the Joseph Haubrich bank, on Yampa River, just above the forks. The bank showed a thickness of 6 feet 4 inches of coal and has a shale roof. This coal lies just above the massive white sandstone that marks the base of the upper group.

About halfway between the forks of Yampa River and the town of Craig, near Woods Ranch, or "Big Bottom," Yampa River cuts through a low anticlinal fold and exposes coals of the middle group along its banks (S). A number of valuable seams are probably accessible here.

Craig district.—Near Craig are two openings on seams presumably of the upper coal group, namely, the Walker bank (U) and the Kimberly bank (T). The Walker bank is on the south side of the river, about 4 miles southeast of Craig. The seam measures 8 feet, and possibly more, of apparently good solid coal. The coal breaks out in cubical joint blocks and is without partings. This bank was opened sixteen years ago, and is usually worked during the winter season. Another seam, exposed about 25 feet lower down, is apparently about 4 feet thick.

The Kimberly bank (T) is on the north side of the river and about 2 miles east of Craig, near the stage road. The seam measured 8 feet of solid coal and is probably slightly thicker, as neither roof nor floor was exposed. It dips 14° N. and has been opened by a slope starting from the surface outcrop. The coal is much weathered near the entrance, but distinctly improves in quality toward the end of the 150-foot slope.

Lay district.—Westward from the mouth of Williams Fork the intervals between the several coal groups decrease notably. A short distance east of Lay the coals of the three groups are embraced within a vertical range of 800 feet. The middle and upper groups in this locality have been prospected but little. Near Lay post-office, within a vertical range of 250 feet, three coal seams have been opened whose aggregate thickness is 41 feet. An additional 4-foot seam is believed to exist within the same range and a 10-foot seam 60 feet higher, making in all 55 feet of coal within a range of 320 feet.

An entry in the lowest seam (called the Sweeney tunnel) exposes 7 feet 10 inches of coal, separated into two nearly equal parts by a 12-inch streak of bone. Beneath a thick layer of bone now used as the floor of the mine another bench of good coal 4 feet thick is reported. One hundred feet above the Sweeney seam is the so-called Peacock seam. Here are 9 feet of coal, unfortunately covered by a poor roof of clay. A 4-inch layer of bone appears near the top, and locally another is found near the bottom. The coal is otherwise clear, bright, and very tough. One hundred feet higher is a double seam containing 20 feet 3 inches of coal, divided into two nearly equal parts by a 15-inch layer of shale. Postmaster A. G. Wallihan, of Lay, the local representative of the Wisconsin Fuel and Mining Company, has driven a broad tunnel about 200 feet into the lower part of this seam. Blacksmith's coal is sent from this mine as far as Hayden, a distance of 45 miles. Simple tests made by Mr. Wallihan lead to the hope that this will prove to be a good coking coal.

WOLF CREEK AND ANTHRACITE RANGE.

The rocks and coal in this district outcrop in a belt of general north-south direction, extending from Grassy Gap, on the west side of Twentymile Park, to the flanks of Sand Mountain, on the east side of California Park, a distance of about 25 miles. The Coal Measures dip toward the west and pass beneath the black shale that forms the rolling prairie land of Hayden Valley. This district includes the coals both north and south of Yampa River, where the three groups cross in the canyon above Hayden. On the north side of Yampa River these are known as the Wolf Creek coals. North of Wolf Mountain this district includes the various coal properties of Anthracite Range.

Wolf Creek Valley.—Wolf Creek drains to the south from Wolf Mountain and joins Yampa River 7 miles above Hayden. In its upper course it flows in a steep, narrow canyon through the massive sandstones that underlie the coal groups. Below this canyon it cuts diagonally across the outcrop of the lower coal group and these coals are well exposed in a number of prospect drifts. One entry, about 40 feet in, showed a face of 4 feet 2 inches of good coal under a shale roof. Below this the stream bed follows near the outcrop of the middle coal group for about 4 miles and these coals are well exposed in a number of recent openings. On Yampa River, opposite the mouth of Wolf Creek, openings have been made on three seams of the middle group, which serve as a good typical section of the group for this vicinity. The uppermost seam measures 2½ feet at its outcrop. Under this are about 70 feet of sandstone and shale, and then the coal known as the Wadge seam, which measured 8 feet 3 inches of clean, bright coal, without parting. This coal seam is locally known as one of the most perfect in the field, as to quality of coal, character of the seam, and its ability to withstand weathering. A sample for analysis was taken at the breast of an old working (K) about 250 feet in and a second sample of the same seam in a recently opened drift (O). Both of these represent the whole face of the seam—8 feet 3 inches of coal.

Analysis of coal from Wadge seam, on Yampa River.

[F. M. Stanton, analyst.]

	Sample K.	Sample O.
Moisture	9.49	10.59
Volatile matter	37.89	36.75
Fixed carbon	47.04	47.53
Ash	5.58	5.13
	100.00	100.00
Sulphur	.41	.44
Loss of moisture on air drying	2.40	4.00

About 90 feet stratigraphically below the Wadge seam is a thick seam of coal opened by an entry driven under the stage road on the north side of the river. This seam measures 16 feet 3 inches, and possibly a little more, of which the lower 7 feet of coal have been mined out. This was separated from the upper 8 feet of coal by 15 inches of sandy parting.

On a side gulch entering Wolf Creek from the east, 2 miles above the river, a seam of the lower group has been opened, exposing coal at least 6 feet 4 inches thick, with two or three thin partings. The partings, however, are not constant. Just over the divide to the east, on Butcherknife Creek, are several openings on coals of this same group. An entry recently made on Mr. Gartman's property (L) exposed coal measuring as follows:

Section of coal on Gartman property.

	Ft.	In.
Coal	5	6
Bone		4
Coal		6
	6	4

A sample representing all but the 4 inches of bone showed the following analysis:

Analysis of coal (Sample L) from Gartman entry, on Butcherknife Creek.

[F. M. Stanton, analyst.]

Moisture	10.92
Volatile matter	36.53
Fixed carbon	46.73
Ash	5.82
	100.00
Sulphur	.60
Loss of moisture on air drying	3.40

Anthracite field.—Intrusive igneous rocks of several types cut the coal-bearing beds at many points. Within the coal field the district in which this activity was greatest centers about Pilot Knob and Wolf Mountain. By far the most common of these intrusive rocks is the basalt that composes Pilot Knob, Wolf Mountain, Hooker Mountain, and many lesser peaks and ridges of this vicinity. The whole district is known as the Anthracite Range. The rock itself is a typical olivine-basalt. The basaltic peaks have the appearance of huge dikes, probably marking the fissures through which this rock ascended. Smaller dikes of approximately vertical position radiate from the larger masses, and sills of the same material are found interbedded with the sediments in many places.

The heat accompanying the intrusion of the molten rock has influenced to varying degrees the character of near-by coals. In general the result of this baking process has been the driving off of the volatile hydrocarbons. In this way all intermediate grades of coal ranging from bituminous to anthracite have been formed.

It is evident that where the source of the heat was fairly uniform in its relation to the coal seams the resulting alteration of the coal may be expected to be correspondingly uniform over a like area. This result is best attained in the cases of the intruded sills. Two reasons may be given for the fact that many of these intrusions have taken the form of sheets lying parallel to the coal seams: (1) The basalt, when molten, is a comparatively fluid magma and more readily forces its way into thin crevices than would the magmas of more acidic rocks. (2) These crevices would more easily open in the sedimentary series between the beds than across them.

On the other hand, the intruded lava sheets do not seem to have exerted an influence through more than 50 to 70 feet of intervening strata, and probably not often so far as this. A contact of coal and lava would probably have resulted in burning or complete coking of the coal. In order that any given seam may be changed to good anthracite there is necessary a comparatively delicate adjustment of this relation of coal seam and lava sheet, the achievement of which depends on purely accidental circumstances.

The property known as the Crawford tract is situated on the county road that crosses the Anthracite Range west of Anthracite post-office. Openings on the seams of this tract furnish perhaps the best known of the anthracized coals. Three entries are located close to the public road. The two uppermost on the road and one on a side gulch to the north appear to be on the same seam. This measures at least 11 feet in thickness, with a parting of 6 to 8 inches near its middle. A massive sheet of basalt is plainly exposed on the north side of the creek, dipping under the lower seam at an interval of about 50 feet. The coal seam shows varying degrees of anthracization. It is thought that this seam corresponds to the lowest seam of the middle coal group as exposed at the mouth of Wolf Creek, both in details of its measurements and in position at the base of the group. Samples (E and G) from two entries on this seam were taken for analysis. They were obtained by making cuts across the face from top to bottom of the lower bench of 6 to 7 feet of coal.

Analyses of coals from 11-foot seam on Crawford tract.

[F. M. Stanton, analyst.]

	Sample E.	Sample G.
	Per cent.	*Per cent.*
Moisture	6.94	6.85
Volatile matter	3.42	23.84
Fixed carbon	75.61	60.00
Ash	14.03	9.31
	100.00	100.00
Sulphur	.57	.55
Loss of moisture on air drying	4.20	4.20

A comparison of these results with analyses of typical Pennsylvania coals, both anthracite and bituminous, shows that Sample E is an exceptionally high grade of anthracite, so far as its percentages of fixed carbon and volatile matter are concerned, but that its commercial value as such is materially impaired by the high percentage of ash.

Sample G was taken from an entry on the same seam, only 40 rods distant. Its composition would class it as a bituminous coal of good quality.

A smaller seam, measuring about 28 inches, has been opened in a number of places a short distance beneath the large seam just described. Reports of analyses of this coal show it to be anthracite of excellent quality, containing only a normal percentage of ash. No statement can be made as to its probable extent.

The lowest opening on the road is on a seam 100 feet or more stratigraphically higher in the series than the seam just described. This coal measured 6 feet 2 inches, without partings, at the breast of a 140-foot drift, and is supposed to be the Wadge seam. A sample (F) cut from the whole face shows on analysis a composition very similar to that of the Wadge coal. This analysis is as follows:

Analysis of coal (Sample F) from bituminous seam on Crawford tract.

[F. M. Stanton, analyst.]

	Per cent.
Moisture	11.74
Volatile matter	35.31
Fixed carbon	47.36
Ash	5.59
	100.00
Sulphur	.56
Loss of moisture on air drying	5.70

To the south and east of the gap above the Crawford mines and near the road are several openings on coal seams of the middle group, so badly fallen in that the coals were not measured. One tunnel near the road was reported to have opened a thick seam of coal that ran high in ash, and it is thought that this may be the same seam as the thicker one opened in the Crawford property, which also carries a considerable percentage of ash, as shown by analyses E and G on page —.

A seam of the lower coal group has been opened and mined for domestic use on the face of a steep ridge in a school section to the east of the openings last mentioned. This opening showed about 8 feet of solid coal, but could not be measured exactly, as the lower part of the coal was standing in water. The seam dips about 10° W. From this point northward the lower coal group outcrops along the east side of Pilot Knob and is exposed in the openings on the head of Miller Gulch and in those near the Ducey tunnel. On Miller Gulch a recently opened prospect was sampled for analysis (H). This sample was cut across the face of a seam 4 feet 1 inch thick.

Analysis of coal (Sample H) from prospect at head of Miller Gulch.

[F. M. Stanton, analyst.]

	Per cent.
Moisture	10.80
Volatile matter	34.32
Fixed carbon	49.41
Ash	5.47
	100.00
Sulphur	.58
Loss of moisture on air drying	5.70

The Ducey tunnel is on the east side of Pilot Knob. It has been worked for about nine years to supply the settlers on the head of Deep Creek, and the coal has been hauled as far as Hahns Peak. The old tunnel showed 5 feet of solid block coal dipping lightly to the west. The coal does not appear to have been affected by its proximity to the huge basalt mass of Pilot Knob. Fifty feet above the old tunnel a seam having a thickness of 5 feet 2 inches has recently been opened.

About 3 miles northeast of Pilot Knob a thick sheet of basalt, known as the "rim rock," is exposed, lying in a nearly horizontal position and interbedded with the lower coal group. The property known as the Shelton tract overlies this intruded sheet. Coals of this tract have been extensively prospected, both by pits and bore holes, and anthracite is reported to have been found over most of the field that lies directly above the basalt sheet. The outcropping rim of the sheet is continuous for a number of miles to the north and it appears to occupy a single horizon in the sedimentary series. If this is true, its effect on the overlying coal seams may have been uniform over a very considerable area.

The outcrop of the coal-bearing series continues, in part, at least, from the "rim rock" northward along the east side of California Park, lapping against the slopes of Sand Mountain. Little is known concerning the coal in this extremity of the field, for much of the ground is covered by débris of igneous rocks.

The field within which the three coal groups are known to have been affected in places by the heat from the intrusion of igneous rocks is probably limited to about 25 square miles. This estimate does not include the Quaker Mountain district, whose coal seams are considered to be of later or Laramie age and in most cases of inferior quality to the older seams of the field, although, as explained in a later paragraph, some of these Laramie coals have been altered to anthracite coal. Of this area of 25 square miles a considerable portion is occupied by the basalt, both as rock in place and in the form of heavy talus cover. The actual area in which anthracite coal is now known to be present or in which conditions seem favorable for its occurrence probably does not exceed 10 square miles.

LOWER ELKHEAD AND FORTIFICATION CREEKS.

The center of the main Yampa field, as mapped, is occupied by a thick series of slightly consolidated beds of light-colored sands and clays, containing many coal seams. This formation appears to lie conformably over the lower beds of Montana age, and, as a few marine shells were found in it north of Hayden, it seems probable that it is of Laramie age. The coal that it contains has been prospected somewhat and in one case at least has been mined for local use.

The Seymour opening (Z), on Dry Fork of Little Bear Creek, a tributary of Fortification Creek northeast of Craig, is on a thick seam of this coal. The roof is a compact blue clay, well exposed for a thickness of 6 feet. This seam of solid, black, bright coal, at least 17 feet thick, shows for 150 feet in natural exposure in the creek bank near by. The coal itself, however, seems to be of comparatively light weight.

The coals exposed at the "potholes" of Elkhead Creek, although in some cases anthracized by the intrusion of igneous sheets, belong to the unconsolidated beds of the Laramie. To this formation also belong most of the coals on Quaker Mountain and some seams on the north side of California Park. At the extreme east end of Quaker Mountain, however, several prospects and tunnels of the Egeria Coal Company (V) have opened seams of coal whose proper classification is not certain. From the character of the associated shales and sandstones it is thought that they probably belong to the Laramie, but owing to the fact that the middle and upper groups of the Montana coals have been lost sight of in this vicinity under the basalt cover, this opening may be on one of these older coal seams.

THE ENGLE COAL FIELD, NEW MEXICO.

By W. T. Lee.

The Engle coal region takes its name from the town of Engle, a station on the Atchison, Topeka and Santa Fe Railway about 100 miles north of El Paso, Tex. It is the southernmost of the small coal areas of central New Mexico and lies about 70 miles south of the Carthage area, in which occur the southernmost productive mines of this region.

The coal outcrops in the western limb of the great syncline of the Jornada del Muerto, and the eastward-dipping beds disappear beneath the surface detritus occupying the center of that syncline. The western edge of the trough in this region consists of the Caballos and the Fra Cristobal ranges, separated by a gap several miles wide, in which the plain of the Jornada extends westward to the Rio Grande.

The geological formations are steeply upturned and are particularly well exposed in the Caballos Mountains. Those beneath the coal range in age from pre-Cambrian to Benton. The coal-bearing strata consist of sandstones and shales several thousand feet in thickness and occupy the gap between the Caballos and Fra Cristobal mountains west of Engle, extending north and south of this gap for several miles before they are finally covered by the surface detritus of the Jornada.

Lignite coal deposits occur at or near the base of the series, while the middle and upper layers contain large quantities of petrified wood. The upper part of the series is composed of red clay, sandstone, and conglomerate and has been mistaken by some for the "Red Beds," which occur at a lower horizon. These red strata, however, contain the bones of Triceratops, a reptile characteristic of latest Cretaceous time.

The relation of the Engle coal deposit to those farther north is not certainly known. Its position in contact with the Benton suggests an early Cretaceous age, while the abundant plant remains, as well as the Triceratops, a supposed Laramie reptile, seem to correlate it with such later Cretaceous coal formations as occur in the Cerrillos or the Raton area.

Little development has been accomplished in the Engle area and its importance as a coal field is doubtful. Only one serious attempt has been made to open a mine. At the time of the writer's visit to this region, in the summer of 1905, a shaft was being sunk on one of the veins at the base of the series, about 10 miles southwest of Engle. The coal is soft, resembling the lignite of other parts of New Mexico, and is apparently of good quality. The coal, so far as developed, is about 1 foot thick, although the carbonaceous shale associated with it is 2 or 3 feet thick. The prospect of finding a deposit of workable thickness was considered promising enough to warrant investigation.

The possible occurrence of coal in this locality assumes importance on account of its proximity to the proposed Government reservoir at Elephant Butte. The dam site of this reservoir is but a few miles from the coal outcrops. Coal in workable quantities would greatly facilitate the work of the Government in the construction of this reservoir, as well as benefit the large number of people that will settle in the vicinity after the reservoir is built.

THE DURANGO-GALLUP COAL FIELD OF COLORADO AND NEW MEXICO.[a]

By F. C. Schrader.

LOCATION.

The Durango-Gallup coal field lies mainly in the northwestern part of New Mexico, but includes also a small area in the southwestern part of Colorado. As shown by the encircling outcrop of its coal-bearing rocks on the accompanying map[b] (Pl. VII), it extends from Durango, Colo., on the north, beyond Gallup and Mount Taylor in New Mexico, on the south, and from near the New Mexico-Arizona line, on the west, to Chama, Elvado, and the Sierra Nacimiento, near the longitude of Albuquerque, on the east.

It is situated in the great Plateau Province described by Powell and Dutton, and includes most of the upper part of the basin of San Juan River, which drains westward and forms one of the most important tributaries of the Colorado. A small area in the southwestern part of the field, including the region about Gallup, also drains to the west by way of Rio Puerco and the Little Colorado. Although located mainly on the western slope, the field extends across the continental divide, whence the drainage from its southeastern border finds an outlet by way of Chama and San Jose rivers and the Rio Grande into the Gulf of Mexico.

The area thus defined comprises the principal part of the coal field as known, but the coal-bearing rocks extend to the northwest and west into Utah and Arizona, and also to the south 50 or 60 miles beyond Gallup. As these outlying areas were not visited during last season, they will not be given further consideration in this paper.

Geographically the field may be characterized as a dissected plateau—a diversified land of mountains, buttes, mesas, terraces, ridges, scarps, valleys, canyons, and arroyos, in which the deeper valleys are nearly 1,000 feet below the general upland level. The highest mountains are on the north and east, and from these summits the surface slopes gently to the west down the valley of San Juan River. The elevations, which vary from nearly 9,000 feet on the continental divide to 5,000 feet in San Juan Valley, are estimated to average about 6,500 feet.

The occurrence of coal at various points in the field has been known for more than half a century through the work of Wheeler, Hayden, and other early explorers. In 1892 R. C. Hills published in Mineral Resources of the United States an account of that part of the field which lies in Colorado, and in 1902 L. S. Storrs prepared and published in the Twenty-second Annual Report of the Survey an account of the entire field in both Colorado and New Mexico.

Coal has been mined for a score or more years at Durango and Monero, in the northern part of the field, and at Gallup and Clarksville, in the southern part. The field as a whole is very important on account of its nearness to the mining centers of Arizona and the Southwest, where coal of any consequence is unknown.

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[a] This preliminary report is to be followed by a fuller description of the field, now in preparation, which will appear as a bulletin of the Survey.

[b] This map was prepared by Mr. M. K. Shaler.

GEOLOGY.

In a broad way the Durango-Gallup coal field is a huge synclinal basin, with a length from north to south of 130 miles and a breadth from east to west of about 100 miles. The coal-bearing rocks form the rim of this basin and dip toward the center at angles varying from a small amount up to 70° or 80°. The area of the basin is approximately 12,000 square miles, and probably it is all underlain by coal-bearing rocks, but in the center of the basin these are deeply covered by younger Tertiary rocks, except where their regular dips are disturbed by local folds or where they are exposed by the erosion of the deeper valleys. Although the area of the field is thus put at 12,000 square miles, it must be understood that in only a small part of this area is the coal near enough to the surface to be workable.

The coal-bearing rocks consist of shales, sandstones, clays, and a few limestone lentils and concretions, and they comprise five groups or formations of Upper Cretaceous age. Where upturned, even at gentle angles, as between Monero and Dulce, near Elvado, at La Plata, and at Gallup, they form hogback ridges, frequently rising several hundred feet above the valleys which occupy the intervening areas of softer shale. The generalized section of the coal-bearing rocks is as follows:

Generalized section of coal and lignite bearing rocks of the Durango-Gallup field.

NORTHERN PART.

Formation.	Character.	Thickness.
		Feet.
Laramie (?)	Friable gray sandstone with sandy shales, containing variable beds of black lignite (in all of the area mapped excepting the belt southward from Montezuma Creek, north of Juanita, Colo.) and massive friable gray sandstone at base.	700–1,000
Lewis shale[a] (Montana)	Sandy greenish and drab shales, with sandy clays, containing occasional thin layers of impure limestone and concretionary masses at different horizons.	2,000–2,500
Mesaverde[a] (Montana)	Shales with interbedded whitish sandstone and variable beds of coal (workable in the Durango, Monero, and Nacimiento districts) with massive gray sandstone at base.	400–1,000
Mancos shale[a] (lower part of Montana and upper part of Colorado).	Soft dark-gray or drab to almost black clay shales, with thin lenses and concretions of limestone. It includes near the base an impure limestone bed 3 feet thick, which outcrops between Horse Lake and the west front of Jemez Peak, New Mexico, and which is the representative of the Greenhorn limestone.	1,200±

SOUTHERN PART.

Formation.	Character.	Thickness.
Shale and sandstone of Montana age, embracing the upper coal group.	Gray clay shales, brown lignitic shales, variable sandstone beds and lignites.	2,000–3,000
Shale and sandstone of Montana age, containing the middle coal group near top.	Massive gray sandstone, buff to drab clay shales and lignites, massive argillaceous sandstones, drab clay shales, with interbedded argillaceous sandstones, and massive gray sandstone at base.	500–800
Colorado shale, including lower coal group near top.	Dark-gray to drab fossiliferous sandy shales, containing lignite beds of economic value only eastward from Marianna Lake.	500–1,000

[a] Names of formations used by Dr. Whitman Cross in La Plata folio (No. 60), Geologic Atlas U. S.

COAL.

For convenience of description the territory examined is divided into eleven districts, which are located around the rim of the basin, as shown on the accompanying map (Pl. VII). In the main these are not separate basins, but are areas in which the occurrence of the coal is fairly uniform and which are generally accessible from certain lines of approach.

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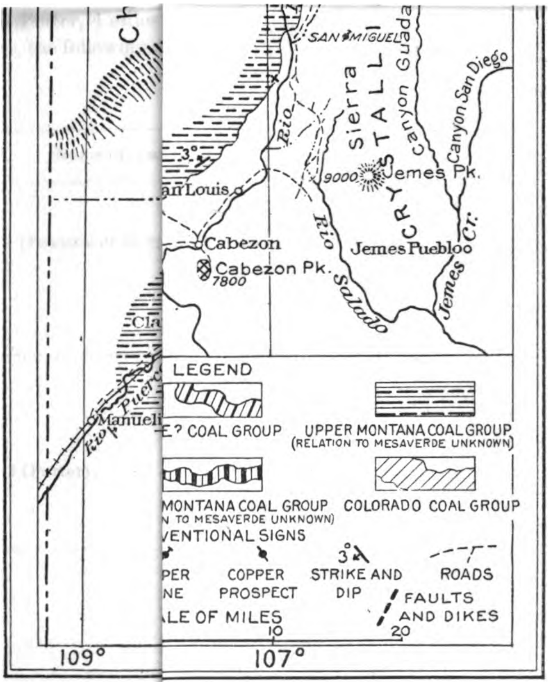

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DURANGO DISTRICT.

The Durango district, one of the most important and at present best developed in the field, is situated on the northern edge of the basin in the foothills of the San Juan Mountains and may be defined as extending from Florida River 25 miles westward, beyond Hesperus and the head of La Plata River. It includes Durango, Hesperus, and Porter and is traversed by the Denver and Rio Grande and the Rio Grande Southern railroads, which in general cross it in an east-west direction.

The rocks of this district incline to the south at angles varying from 10° to 30°, and are trenched by Animas River and its fellow tributaries of the San Juan, which have sunk their valleys about 1,500 feet below the general upland surface, exposing excellent sections of the rocks and coal beds.

The best coal of the district is found near the middle of the Mesaverde formation. The coal beds of this formation constitute a group that is interbedded with a great mass of whitish-yellow sandstone, which generally forms ridges and other conspicuous topographic features. These beds are most extensively mined at Durango, Porter, and Hesperus. The bed mined by the City Coal Company, of Durango, in Horse Gulch, east of Animas River, is 3 or more feet in thickness, without a parting. The following is a partial section of the coal bed in the old Champion mine, belonging to the same company, on the west side of the river:

Section of coal bed in Champion mine 2 miles southwest of Durango, Colo.

	Ft.	In.
Sandstone roof.		
Draw slate (variable in thickness).		
Coal	2 to 3	6
Hard slate floor.		

At Porter, 4 miles west of Durango, where the coal has been mined for about seventeen years, the following section was measured:

Section of coal beds in Porter mine, Porter, Colo.

Name of coal bed.	Section.	Thickness.	
		Ft.	*In.*
No. 1 (Peacock or Hesperus)	Coal, with dirt seams		5
	Coal	2	4½
	White sandstone	70–75	
No. 2	Coal	1	3+
	Sandstone		8
	Coal	2	9
	Shale		3
	Coal	10	
	Sandstone	20–24	
No. 3 (Porter)	Coal (not mined)	0–1	6
	Shale	0–2	
	Coal	2	10+
	Fire-clay floor.		

At present work is carried on almost exclusively on the No. 3, or Porter bed, but a large amount of coal has been taken from coal bed No. 2 and a new mine is being opened on the upper or No. 1 bed. At this mine the coal is screened into three grades—lump, nut, and slack. The lump and nut are sold for domestic and steam purposes and the slack, amounting to about one-quarter of the output, is sold to the smelter company for the manufacture of coke. The coke is of fair quality, and it is claimed to equal, if not excel, any other coke produced in Colorado.

A sample of this coal was taken last summer in connection with the coal-testing work at St. Louis. The sample was obtained by making a cut across a working face of the coal, including all of the coal from roof to floor. The sample was crushed and quartered down to convenient size and sent in a sealed can to the chemical laboratory at St. Louis, where it was analyzed with the result shown in analysis No. 11 on page 258. According to this analysis the coal is of a particularly high grade, being low in sulphur, moisture, and ash, and high in fixed carbon.

The coal beds of this group are also worked at Hesperus, 10 miles from Durango, in the western part of the district. In this locality there are three beds which seem to correspond to those at Porter and Durango. Two mines have been opened, the Hesperus mine, by the Porter Fuel Company, and the Ute mine, by the Ute Coal Company. Both of these mines are in the lowest coal bed, which is believed to be the same as the Porter bed. The only mine in operation is the Hesperus mine, which is situated on the Rio Grande Southern Railroad, and practically all of the output is shipped over this line.

At a geologic horizon about 2,500 feet above the Mesaverde formation occurs a group of coal beds near the middle of the Laramie (?) formation. The coal of this group is of poorer quality than the Porter coal just described, but on account of the thickness of the beds it may prove to be of considerable value.

The best exposure of this coal is about 3 miles south of Durango, at Carbon Junction, formerly known as Carbonero, and from this place the coal is usually known as the Carbonero coal. It was once mined here, and a partial section at the now abandoned mine is as follows:

Section of Carbonero coal bed near Carbon Junction, 2½ miles south of Durango, Colo.

	Feet.
Terrace gravel, surficial	4
Coal, with thin shale seams	20
Shale, drab	2
Sandstone, argillaceous	3
Débris-covered interval	15
Coal, with thin shale seams	22
Shale	4
Sandstone	150

The same coal bed was formerly worked at the La Plata mine, east of Carbon Junction, where it has a thickness and section similar to those on Animas River. When in operation, this mine was connected with the Denver and Rio Grande Railroad by a spur from Arboles.

LOS PINOS RIVER DISTRICT.

The Los Pinos River district lies east of the Durango district and extends from Florida River eastward across Los Pinos River, Piedra River, and Rio Nutria. Like the Durango district, it lies mostly in the foothills of the San Juan Mountains, where they give way to the plateau country on the south. It contains both Mesaverde and Laramie (?) coal of good quality, but, having no railroad facilities, the mines are small and the output is limited to local demands. The coal beds of the Mesaverde formation extend eastward from Durango across Florida River. Where they cross the Florida, a coal bed of this group has been opened at the Perkins & Rockwood mine, showing the following section:

Section of coal bed at the Perkins & Rockwood mine, 7½ miles northeast of Durango, Colo.

Name of coal bed.	Section.	Thickness.	
		Ft. in.	*Ft. in.*
No. 1 (Peacock or Hesperus)	Coal, dirty	5	2 9½
	Coal	2 4½	
	Sandstone, white		72 0
No. 2	Coal	1 3	5 9
	Sandstone	8	
	Coal	2 9	
	Shale	3	
	Coal	10	
	Sandstone		22 0
No. 3 (Porter)	Coal, variable (not mined)		3 0±
	Shale, variable		
	Coal	2 10	
	Fire clay.		

In early days this coal was coked and the product was hauled to Durango for smelting purposes. Coal of a similar quality and thickness is reported to occur in the Mesaverde formation near Pagosa Springs, on Rio Nutria, but between Florida River and the Monero district no workable coal was observed in this formation.

The Laramie (?) coal group is much more extensively distributed, exposed, and worked in this district than the Mesaverde, and it usually includes two or more beds. Slopes have been driven in on one of these beds near Florida River, about 1 mile south of the Perkins & Rockwood mine, and the following section is exposed:

Section of coal bed at old mines 7½ miles northeast of Durango, Colo.

	Ft.	In.
Sandstone.		
Coal[a]	3	
Shale		8
Coal[a]	4	
Sandstone.		

East of this point the coal beds of this group make only a slight showing for a number of miles. Owing to the scarcity of exposures, it is difficult to determine their exact condition, but they are probably of workable thickness. An opening on the head of Texas Creek, 9 miles northwest of Bayfield, shows the following section:

Section of coal bed in Carleton's coal mine, 9 miles northwest of Bayfield, Colo.

	Ft.	In.
Black shale and bony coal.		
Coal	1	2
Shale	1	8
Coal		8
Shale		8
Coal	1	2
Bony coal.		

---

[a] The quality of this coal is unknown, but according to report it has been tested and found to be "semicoking."

Farther southeast the coal beds of this group are of workable proportions, as shown by the following section near Beaver Creek, a tributary of Los Pinos River:

Section of coal bed in sec. 17, T. 35 N., R. 6 W., 1¾ miles north-northwest of J. W Love's ranch, near Beaver Creek, Colorado.

	Ft.	In.
Sandstone	5	
Draw slate	1	
Coal	5–6	
Bony coal		6
Coal	2	4
Sandstone.		

On the head of Beaver Creek, where this bed is worked in the Black, Wheeler, and other mines, its section is substantially as follows:

Section of coal bed in Wheeler mine, at head of Beaver Creek, Colorado.

	Ft.	In.
Coal	2	
Shale	15	
Coal, bony	1	2
Coal	2	8½
Coal, bony		1
Coal		5

A sample was taken at this mine for chemical analysis by making a cut from roof to floor across the face of the coal, exclusive of the bony coal parting 1 inch in thickness. This sample, consisting of about 25 pounds of coal, was crushed to about one-half inch size and quartered down until a quart sample was obtained. This was sealed air-tight in a galvanized-iron can and sent to the coal-testing plant at St. Louis for analysis. The result is given in analysis No. 1, on page 258. This shows the sample to be a good grade of bituminous coal, with a fairly low percentage of moisture and sulphur, but a high percentage of ash. The great amount of ash is the principal defect in this coal, which otherwise seems to be a steaming coal of good quality.

South of Beaver Creek the sandstones associated with the Laramie (?) coal group form a line of hogbacks trending nearly south to the head of Yellowjacket Creek, a tributary of Piedra River. The coal has been opened at several places along this line, but only a few of these prospects were visited. An opening on the Glenn ranch, on Yellowjacket Creek, shows a section of about 100 feet in which there are three coal beds, measuring, in ascending order, 6 feet, 4 feet, and 13 feet in thickness. Five miles farther south, near the Big Bend of the creek, the coal has been well prospected, and it is reported to be changed locally to anthracite and to contain natural coke.

Down the Piedra from the mouth of Yellowjacket Creek to Rio Nutria and extending a few miles up the latter stream the outcrops of coal are more or less continuous, and since the rocks are only slightly inclined, the coal beds underlie a considerable area between the Piedra and Nutria. At a number of points in this region the coal has lost much of its value by fire, which locally has burned out some beds and deteriorated others.

MONTEZUMA MOUNTAIN DISTRICT.

The Montezuma Mountain district lies to the east of the one just described and extends from west of Gato Creek and the Rio Grande, Pagosa and Northern Railroad southeastward across San Juan River to the New Mexico line. The Laramie (?) alone is coal bearing in this district, or at least this is the only formation in which workable coal was found The coal has been mined by whites and Indians in the hills west of Gato Creek and in the mesa contiguous to Archuleta Mountain, east of San Juan River. Near the latter place the principal coal bed caps Montezuma Mountain, and for that reason is currently known as the "Montezuma 11-foot vein." Prospects have been opened on San Juan and Navajo rivers several miles above Juanita, but the only point of commercial production at present is the Talian mine, situated on Indian land 4 miles north of Pagosa Junction, on the Rio Grande, Pagosa and Northern Railroad. At this mine the dip of the rocks is 26°, and a section of the coal beds exposed is as follows:

Section of coal beds in Talian mine, 5 miles north of Pagosa Junction, Colo.

	Ft.	In.
Shale, arenaceous.		
Coal	4	
Sandstone, mostly thin bedded	16	
Sandstone, heavy bedded	2½	
Shale, arenaceous		6
Coal	2½- 3	

The coal is used principally for steam and domestic purposes.

At the Archuleta tunnel (abandoned), 7 miles northeast of Juanita, the coal was mined some years ago and used in drilling for oil at the head of Montezuma and Coyote creeks. The coal bed consists of 10+ feet of good coal, including two shale partings varying from 1 to 2 inches in thickness. The floor and roof are shale, and the dip of the beds is to the southwest at the angle of about 5°.

MONERO DISTRICT.

The Monero district extends from Navajo River, at the Colorado line, southward along the Continental Divide to Horse Lake, New Mexico. It lies in the plateau proper and apart from the foothills of the San Juan Mountains, from which it is separated by the Chama Valley. It is bounded on the east for the most part by a prominent eastward-facing escarpment several hundred feet high, formed by the upturned edges of the Mesaverde sandstone, which here forms the Continental Divide and is locally known as the "rim rock." It drains to the west by way of Amargo Arroyo into Navajo River.

In this district the coal beds of the Laramie (?) are thin, shaly, and unimportant, but the Mesaverde formation contains two main beds of workable thickness and of about the same quality as the Mesaverde coal in the Durango district. The coal contains much fossil resin, which accelerates its combustion and renders it desirable for domestic use.. It is a coking coal, and its chemical composition is shown in analyses Nos. 12 and 13 in the table on page 258.

The only locality at which mining is done on a commercial scale is Monero, which is located near the center of the district, on the Denver and Rio Grande Railroad. At this place the general dip of the rocks is about 4½° W., but this is far from regular, as the beds are cut by a number of faults which disturb their dip and continuity.

Three mines have been opened at Monero. The Kutz mine was temporarily shut down at the time it was visited, but considerable coal has been taken from it. The section of the coal beds exposed in this mine is as follows:

Section of coal beds in Kutz mine, Monero, N. Mex.

	Ft.	In.
Shale.		
Coal, upper	3	5
Shale.		
Sandstone	50	
Shale	1	
Coal, lower	3	4
Shale.		

A sample was taken of the upper bed at this mine for chemical analysis. The material for the sample was obtained by making a cut across the face of the coal from roof to floor, a distance of 3 feet 5 inches, and as there are no partings in the coal the sample contained everything in the bed. This material was pulverized and quartered down at the mine until a quart sample was obtained, and this was sealed air-tight in a galvanized iron can and sent to the laboratory for analysis. The result is shown in analysis No. 12 in the table on page 258.

The McBroom mine is working on the upper coal bed and the Monero mine on the lower bed of this group. The main gangway of the latter is driven down on the slope of the coal for about 1,600 feet. A sample for chemical analysis was taken from this mine in the same manner as from the Kutz mine. The material of the sample was obtained from a cut made across the entire face of the coal bed 33½ inches in thickness. The result is shown in analysis No. 13 in the table, on page 258. The analyses of the samples from the two mines are very similar, except in the amount of sulphur and ash. The percentage of sulphur in the Kutz sample is remarkable, and exceeds that in any other sample obtained from this field. Aside from the ash and sulphur there is a great similarity in the composition of the two samples, and they both rank as fairly high grade bituminous coals.

The output of the district is about 40,000 tons per year, three-fourths of which is from the Monero mine. About 15 per cent of the total product is fine coal, which now is wasted for lack of coking facilities. Eighty per cent of the merchantable coal is used by the Denver and Rio Grande Railroad for locomotive coal, 12 per cent goes to the New Mexico Lumber Company, and the remainder is used in home consumption and a limited commercial trade.

Heretofore the coal has sold readily for $1.50 per ton, but at present the ruling price is $1.25 per ton. The Rio Arriba Coal Company, which operates the Monero mine, estimates the coal now in sight on its ground at 5,000,000 tons, which will enable this mine to continue its present rate of production for considerably more than a century.

At Lumberton the coal has been worked, but only to supply the local demand. The beds dip slightly to the west, but they are more broken by faults than at Monero. The following section was measured in a gulch 1 mile southeast of Lumberton:

Section of coal bed 1 mile southeast of Lumberton, N. Mex., in sec. 3, T. 31 N., R. 1 W.

	Ft.	In.
Shale and sandstone.		
Sandstone	1	
Coal	3	
Coal, bony		4
Sandstone	1	6
Coal, bony	2	
Coal	2	
Coal, bony		6
Shale and sandstones	40	
Sandstone		6
Coal	1	
Shale.		

The coal beds seem to grow thin south of Monero, as shown by the following section which was measured near Horse Lake:

Section of coal bed in sec. 1, T. 30 N., R. 1 E., about 8 miles southeast of Monero, N. Mex.

	Ft.	In.
Sandstone	2	
Shale		6
Coal	2	6
Shale	3	
Coal	1	6
Shale	3	
Sandstone	2	
Shale		6
Coal	2	
Shale.		

STINKING LAKE DISTRICT.

The Stinking Lake district lies west of Chama River and Elvado, and extends from Boulder Lake southward beyond Stinking Lake. It drains east into Chama River. No mines have been opened in this district. Some good coal is present, but probably it does not occur over large areas or in promising quantities. The Mesaverde is the coal-bearing formation, and the hogback formed by its hard beds constitutes the continental divide as at Monero. From the summit of this hogback the dip is gently westward and the rocks pass by low dips under the San Juan basin to the west. The beds are well exposed near the northeast shore of Boulder Lake and the Elvado Railway. In general little is known regarding the coal of this district, but it shows in places in natural exposures, as indicated by the following section, which was measured near Boulder Lake:

Section of coal bed near the railroad, one-fourth mile northeast of Boulder Lake, New Mexico, in sec. 18, T. 29 N., R. 1 W.

	Ft.	In.
Sandstone	2	
Shale, coaly at base	1	2
Coal (good quality)	2	3
Sandstone, argillaceous		3
Coal (good quality)	2	1
Shale.		

At Stinking Lake the coal outcrops at intervals along the east shore, which is several miles in extent. Although it is easily accessible and the beds aggregate 10 feet in thickness, the coal is so broken by partings as to be of little value. The section is as follows:

Section of coal bed on the east shore of Stinking Lake, New Mexico, in sec. 20, T. 28 N., R. 1 W.

	Ft.	In.
Shale with thin sandstone	60	
Coal		4
Shale, black		2
Coal	1	8
Shale, black	4	
Coal	1	3
Shale, black	3	
Coal	1	
Shale, black	35	
Shale, arenaceous		3
Sandstone	1	
Shale, arenaceous	15	
Sandstone, argillaceous	10	
Shale, black	18	
Sandstone	2	
Coal	1	
Shale	1	6
Sandstone		4
Shale, black	2	6
Coal	1	8
Shale	1	2
Sandstone, ferruginous		8
Shale		2
Coal	1	
Shale	10	
Coal		10
Shale		2
Coal	1	3
Shale		2
Sandstone	20	
	195	1

GALLINA DISTRICT.

The Gallina district lies south of the one last described, and extends from 12 miles north of Gallina to the divide between Gallina and Puerco rivers, a distance of 15 miles, and flanks Gallina Mountain on the west. No mining has been done in the district, but the coal appears to be of good quality and is workable, and with the installation of transportation facilities may become an important factor in the fuel supply of the Southwest.

The workable beds occur in the Mesaverde formation, which is exposed in the lower dip slopes of a prominent hogback, in which the beds are upturned at angles varying from 20° to 40°.

In the north end of the field, near the Elvado-Gallina road, a natural outcrop shows the following section of the coal beds:

Section of coal beds near Elvado road, 12 miles north of Gallina, N. Mex.

	Ft.	In.
Sandstone	40	
Shale	3	
Coal	1	6
Shale	4	
Coal	5	6
Shale, carbonaceous		6
Coal	1	
Shale	25	

Three miles west of Gallina the same rocks are exposed, and the following section was measured:

Section of coal beds 3 miles west of Gallina, N. Mex.

	Ft.	In.
Sandstone	20	
Shale	12	
Coal		3½
Shale	50	
Coal	2	9
Shale, with five coal beds ranging from 3 to 12 inches thick	100	

As the coal beds incline to the west from the hogback, which limits the field on the east, they pass beneath the surface of an open valley or sage-brush flat nearly 100 miles in areal extent, and since the dip generally decreases toward the center of the basin the coal beds can probably be reached at a moderate depth by shafting, an important point in the prospective economic development of the district. An ample supply of timber suitable for mining purposes may be found on Gallina Mountain near by, and thus all natural conditions are favorable for economic mining.

All the coal beds so far described in this district occur in the Mesaverde formation, but the Laramie (?) also contains coal, as shown by the outcrop of a bed of good coal 12 to 15 inches thick 7 miles north of Gallina. This is noteworthy as being the first good coal found in the Laramie (?) formation south of Navajo River.

NACIMIENTO DISTRICT.

The Nacimiento district flanks the west base of the Sierra Nacimiento, and extends from north of Lajara nearly to San Miguel, below Senorita, a distance of about 16 miles. In general the coal-bearing rocks dip steeply to the west, but in come localities they are overturned and dip in the opposite direction. Between Lajara and Cuba they are exposed only in the heads of deep canyons or cirques, cut through the overlying Tertiary and the talus and wash along the base of the mountains.

Near the site of the old Copper City smelter, however, 3 miles east of Cuba and 2 miles north-northwest of Senorita, the hogback formed by the Mesaverde is exposed and the following section was measured:

Section of coal bed near site of old Copper City smelter, 2 miles north-northwest of Senorita, N. Mex.

	Ft.	In.
Sandstone	3	
Shale, brown carbonaceous	2	
Coal	1	
Shale, brown carbonaceous	2	
Coal	5	6
Shale	2	
Sandstone	4	6

The coal in this bed is of good quality and has been mined for local use. The rocks are overturned and dip east, toward the mountain, at an angle of about 70°.

The same coal bed has been opened by the roadside near Senorita, 2 miles south of the above-mentioned locality, and mined by the Juratrias and other copper companies. The coal was used for steaming and smelting, as well as for domestic purposes. It is of good quality and is reported to have given general satisfaction. The coal bed is about 6 feet thick and inclines steeply to the east at an angle of about 70°, the measures being overturned, as at Copper City.

South of Senorita the coal outcrops at intervals for a distance of several miles, nearly to the place where the Mesaverde formation, still upturned and on edge, disappears below overlying younger formations. Beyond this place the formation seems to extend a long distance to the south and probably carries the coal beds that are reported west of Albuquerque. About a mile north of the place, where the Mesaverde formation disappears, it is unconformably in contact on the west with coal-bearing rocks, which lie nearly flat and are younger than the Mesaverde and form the Chico Arroyo district, described below. The contact between these two formations is due to faulting.

CHICO ARROYO DISTRICT.

The Chico Arroyo district extends from the western base of the Sierra Nacimiento, between Senorita and San Miguel, southwestward nearly to San Mateo and Mount Taylor, a distance of nearly 60 miles.

The coal beds are associated with clay, carbonaceous shale, and sandstone, which aggregate a thickness of from 2,000 to 3,000 feet, and are regarded as a great coal-bearing group; but, as previously noted, they are faulted in contact with the Mesaverde formation on the east, and so it was impossible during this reconnaissance to determine their exact relations and geologic horizon. Some invertebrate fossils were found in them, however, which indicate that they belong above the Mesaverde formation, in the upper part of the Montana. Hence, on account of its relative position in the series, the group is here designated the upper coal group of the Montana formation.

Throughout the district the beds in general dip about 3° in a direction slightly west of north. The coals are exposed mainly in the scarp formed by the southeastern edges of the rocks along Rio Puerco and the head of Torreones Arroyo and underlie the Chacra Mesa and the lava-capped plateau of the Sierra Chivato. The following sections were measured at separate localities well distributed throughout the district and give a fair idea of the character of the coal beds of this group:

Section of coal bed in the mesa west of Rio Puerco, 15 miles north-northeast of Cabezon, N. Mex.

	Ft.	In.
Sandstone	3	
Shale	3	
Coal	3	
Shale, brown carbonaceous	1	3

Section of coal bed 3 miles above mouth of Arroyo de los Torreones, 10 miles west-northwest of Cabezon, N. Mex.

	Ft.	In.
Shale	2	
Coal	2	6
Coal, bony		3
Shale	1	8
Coal	1	8
Shale	5	

Section of coal beds in the mesa 1 mile north of Chico Arroyo, about 16 miles west of Cabezon, N. Mex.

	Ft.	In.
Alternating beds of sandstone and shale	20	
Shale, brown, carbonaceous	5	
Coal	3	3
Shale, brown, carbonaceous	2	
Shale	20	
Coal	1	
Sandstone	20	
Coal	1	

Section of coal beds three-fourths of a mile north of the Cabezon-San Mateo road, 23 miles from Cabezon, N. Mex.

	Ft.	In.
Shale, arenaceous	5	
Coal	1	
Shale, brown, carbonaceous		6
Sandstone and shale interbedded	8	
Shale, brown, carbonaceous	2	
Coal	2	9
Shale, brown, carbonaceous.		

Section of coal bed 5 miles north of Alesna Peak, New Mexico.

	Ft.	In.
Shale, brown, carbonaceous.		
Coal	2	6

Section of coal bed in arroyo 2¼ miles north of the Cabezon-San Mateo road and 5 miles west-southwest of Alesna Peak, New Mexico.

	Ft.
Shale.	
Coal, with thin, bony partings near top and middle	5
Shale.	

No development has been undertaken in this district. The coal is a good grade of black lignite and in appearance compares favorably with the Carbonero coal and with that of Gallup and Fruitland, to be described later. It is probably of workable thickness throughout an area of at least 300 square miles.

HOSTA BUTTE DISTRICT.

The Hosta Butte district extends north of west from San Mateo and Mount Taylor across the continental divide nearly to Gallup, a distance of about 60 miles. It lies about 12 miles north of the Atchison, Topeka and Santa Fe Railway, and contains three groups of coal-bearing rocks, upper, middle, and lower.

The upper coal group was observed only in the northwestern part of the district, in the southeast corner of the Navajo Indian Reservation, where it has an extent of about 30 miles in an east-west direction. From the similarity of its beds it is correlated with the upper coal group of the Chico Arroyo district, which has been referred to the upper part of the Montana, and with which the beds probably connect beneath the plain along the north border of the Hosta Butte district. Owing to scarcity of outcrops, however, this connection has not been traced. The beds of this district also seem to connect with those at Gallup, to be described later, and it is also probable that they bear the coal reported to occur 30 to 40 miles north of the Hosta Butte district out in the basin, at Stony Butte and beyond Rio Chaco.

The middle and lower coal groups enter the Hosta Butte district from the direction of Mount Taylor and, after extending northwestward across the district, curve southward and form the hogback, which crosses the railroad 3 miles east of Gallup. Their geologic age is not definitely determined, but from the evidence of a few fossils collected in each of them it is probable that the middle group represents the lower part of the Montana formation and that the lower group represents a part of the Colorado formation.

In the center of the district, near Hosta Butte, the vertical interval between the groups is about 500 or 600 feet. In general, the dip of the rocks is to the north and the coal beds are exposed in southward-facing escarpments, but where the rocks are sharply upturned, in the hogback east of Gallup, they do not seem to carry coal in workable amount.

The coals of this district have been little prospected, but they show in natural outcrop at many localities. The better-known exposures lie along the Grant-Farmington road, the Thoreau-Seven Lakes road, the Devils Pass trail, near Lake Mariana, and at Hosta Butte, where the rocks are raised into a low dome.

So far as known, the lower coal group contains only one workable bed, which, as shown in the following section, is about 2½ feet in thickness:

Section of coal bed of lower coal group in the mesa 15 miles north-northeast of Thoreau, N. Mex.

	Ft.	In.
Shale.		
Coal	2	6
Draw slate		3
Coal		10
Shale, brown, carbonaceous	2	
Shale and sandstone	20	
Coal	1	
Shale, brown, carbonaceous.		

A similar section is exposed 15 miles north of Bluewater, at the J. E. Tiejen prospect, on a coal bed that is supposed to be the same as the one noted above.

Coal is more abundant in the middle group than in the lower. The former contains a vast amount of coal, as shown by the areal distribution of the measures on the map (Pl. VII) and the coal beds given in the following sections:

Section of coal beds near the Farmington road, 25 miles west of San Mateo, N. Mex.

	Ft.	In.
Shale.		
Coal	2	6
Coal, bony		2
Coal	2	6
Shale.		
Shale and sandstone interbedded	25	
Coal	2	6
Shale.		

Section of coal beds in Devils Pass, 4 miles east of Hosta Butte, N. Mex.

	Ft.	In.
Sandstone, heavy.		
Shale	10	
Coal	3	6
Shale and sandstone	25	
Shale.		
Coal	3	6
Shale.		
Shale and sandstone	10	
Shale	8	
Coal	1	
Shale and sandstone	20	
Shale.		
Coal	1	6
Draw slate	1	
Coal	1	6
Shale.		
Shale and sandstone	100	
Shale, brown, carbonaceous	1	
Coal	2	
Shale	3	
Coal	2	
Shale, brown, carbonaceous	1	
Shale	2	

	Ft.	In.
Shale, brown, carbonaceous	1	
Shale and sandstone	100	
Shale, brown, carbonaceous	1	
Coal	1	
Shale, brown, carbonaceous	1	
Shale	2	
Coal, containing much fossil resin	2	
Shale, brown, carbonaceous	1	
Total coal	21	6

Section of coal bed at Tiejen prospect, on Seven Lakes road 17 miles northeast of Thoreau, N. Mex.

	Ft.	In.
Shale, carbonaceous	1	
Coal	1	3
Shale, arenaceous		1¼
Coal	3	6
Shale, carbonaceous.		

The coal is a good black lignite and contains much fossil resin, resembling in this respect the Monero coal. A sample was taken from the Tiejen prospect for analysis. The material was secured by making a cut across the face of the coal, exclusive of the parting 1¼ inches in thickness. The coal was crushed and quartered down to a quart sample, which was sealed air-tight in a galvanized-iron can and sent to the laboratory at St. Louis. The result is shown in analysis No. 10 of the table on page 258. With the exception of the heavy percentage of water, this analysis compares favorably with the analyses of other coals of the field.

GALLUP DISTRICT.

The Gallup district extends from the hogback 3 miles east of Gallup westward beyond Defiance, a distance of about 12 miles. It is crossed by the Atchison, Topeka and Santa Fe Railway and is the oldest, best known, and most productive district in the field. The coal-bearing group of rocks of this district, so prominent around Gallup, lies higher in the series than the groups that form the hogback east of Gallup. Its geological horizon has not been well determined, but from some fossil plants found at the Weaver mine, north of Gallup, it is referred to the upper part of the Montana formation and is probably the same as the upper coal groups of the Chico Arroyo and Hosta Butte districts. It is divided into upper and lower subgroups, which are separated by about 500 feet of sandstone and sandy shale. In the immediate vicinity of Gallup the dips are from 2° to 15° NW., but they vary in direction, as the rocks are gently folded. In general this part of the field has the structure of a syncline with the rocks dipping toward the center from each side. The synclinal axis is known to extend south of Gallup into the Zuñi Plateau, but this area was not examined during the present reconnaissance. The upper subgroup of coal-bearing beds is about 100 feet in thickness and, as shown by the following section, based in part on data obtained from the American Fuel Company at its Gallup and Weaver mines, contains six workable beds of coal:

Section of upper coal subgroup at the Gallup and Weaver mines 3 miles north of Gallup, N. Mex.

	Ft.	In.
Sandstone.		
Coal	1	
Fire clay	2	
Dirty coal—bed No. 1	3	6
Sandstone and shale	14	
Coal		6
Fire clay	7	
Coal—bed No. 2	4	6
Sandstone and shale	13–36	
Sandstone.		
Coal—bed No. 3	4	

	Ft.	In.
Fire clay	2	
Sandstone	5	
Draw slate	1	6
Coal—bed No. 3½	6	3
Fire clay	2	6
Sandstone, shale, and thin coal seams	20	
Coal, with many shale partings—bed No. 4	3	
Fire-clay floor.		
Sandstone	20	
Coal—bed No. 5	6	6

The lower subgroup contains four workable beds, known as the Crown Point, Thatcher, Black Diamond, and Otero. The following is a partial section of this subgroup at the Otero mine:

Section of lower coal subgroup at Otero mine, 1½ miles east of Gallup, N. Mex.

	Ft.	In.
Coal—Crown Point bed	3	5
Shale		8
Coal	1	5
Sandstone	11	
Coal—Thatcher bed	4	
Shale and sandstone	6	
Shale	9	
Coal—Black Diamond bed	1	6
Sandstone and shale	88	
Coal	1	2
Shale		9
Coal—Otero bed	3	2
Shale(?).		

Of the dozen mines in the district, those now producing are the Weaver, Otero, Heaton, Rocky Cliff, Union, and Clark. The Weaver mine is the most important. Its record output is 2,250 tons per day. Its gangways extend 3,000 feet in, and diamond-drill prospects 4,000 feet beyond the working faces show that the coal beds continue at least to that distance without perceptible change, either in thickness or quality of coal.

The total output of the district in 1903 was 569,362 short tons and in 1904, 441,865 short tons. The decrease in the output for 1904 is due in large measure to the introduction of fuel oil as a substitute for coal on the locomotives of the Atchison, Topeka and Santa Fe Railway. The market value of the coal at the mines is $1.32 per ton. The number of men employed in the district is 700.

The coal of this district is a black shining lignite which approaches bituminous coal closely in composition. Its principal defect is that it crumbles on exposure to the air and is so light that when used in locomotives a large proportion of it is carried out of the stack. Samples for chemical analysis were taken at the Weaver, Otero, and Clark mines. Those representing the Weaver and Otero mines were secured in connection with coal tests that were made in 1904 at the Geological Survey coal-testing plant at St. Louis.

In the Weaver mine the samples were obtained from beds No. 3 and No. 3½ by cuts across the face of the coal from roof to floor, including everything, as the beds are free from partings of any kind. These large samples were pulverized and quartered down to quart size and sent in sealed cans to the laboratory at St. Louis. Analysis No. 5, on page 258, represents the sample from bed No. 3½, and analysis No. 6 that from bed No. 3.

Similar samples were taken from the Otero mine, every precaution being taken to insure their representative character. Analysis No. 7, on page 258, represents the sample from the Crown Point bed, No. 8 that from the Otero bed, and No. 9 that from the Thatcher bed. The sample from the Clark mine was obtained during the course of the present work. It was obtained by making a cut across the working face of the coal, 8½ feet in thickness, and included everything except two partings 1 inch and 3 inches thick. This sample was treated in the usual manner and its character is shown by analysis No. 4, on page 258.

FRUITLAND DISTRICT.

The Fruitland district lies in the northwestern part of the field and extends from near Bennetts Peak on the south to the State line above Pendleton, on La Plata River, a distance of 50 miles. The limits thus defined are not marked by natural boundaries, but simply show the extent of the work of this party. To the northeast the coal-bearing beds are doubtless continuous with those of the Durango district, but they were not followed through. To the south little is known regarding the extent of the outcrop. It seems probable that the beds in the Fruitland district extend to Gallup, but if so they are probably largely concealed under the Choiskai Mesa.

The coal of this district is best known in the vicinity of Fruitland, where it is crossed by San Juan River, and at Pendleton, on La Plata River. Both the Mesaverde and the Laramie(?) coal groups are present, but the former has not produced coal, though it probably carries beds of workable thickness. The rocks of this group are exposed in the hogback which crosses San Juan River at Jewett and Chaco River 4 miles to the south. At the latter point they dip about 40° E. and contain two coal beds which measure 3 feet and 1 foot, respectively, in thickness and which are separated by a shale interval of about 25 feet. In the northern part of the district, a few miles west of Rio La Plata, the coal is reported to occur in three beds, 6 feet, 1½ feet, and 5 feet thick. Some of it appears to be of excellent quality and resembles the peacock coal of Durango.

The Laramie(?) rocks, which occur about 2,000 feet above the Mesaverde formation, flank the Jewett hogback on the east. From this line of outcrop they extend to the east beneath the mesa in a nearly horizontal attitude. They consist of sandstone, shale, and coal, as described in the Durango district. Some of the coal beds are remarkably thick, but for lack of railroad facilities the production is small, not exceeding the local demand.

At Cottonwood Arroyó and along the Chaco east of the hogback the coal crops out in the escarpment near the surface of the mesa, but at Fruitland the northeasterly dip carries it down nearly to San Juan River, in whose bluffs it is exposed on both sides of the valley.

The most important mines at Fruitland are the Hebrum and the Young, favorably located on the public highway 1½ miles northwest of the village. The Young mine is the only one now in operation. It has furnished practically all of the coal used by Fruitland, Jewett, Shiprock, Farmington, and the surrounding country for a number of years. It has two gangways about 100 feet apart, trending N. 30° W., while the strata dip to the northeast. The total thickness of the coal beds is about 16 feet, the section being as follows:

Section of coal bed at Young mine, 1½ miles northwest of Fruitland, N. Mex.

	Ft.	In.
Shale	2-3	
Coal	4	
Coal, bony		6
Coal	5	
Draw slate		2
Coal	2	
Draw slate		2½
Coal (mined)	5	
Fire clay.		

Only the lower 5-foot bed is now worked. A sample of this bed was taken for chemical analysis. It was obtained by making a cut from roof to floor, including all of the coal worked. This was crushed and quartered down to convenient size and sent in a sealed can to the chemical laboratory. The result, as shown in analysis No. 3 on page 258, is approximately the same as the analyses of the Gallup coal.

At the Bruce mine, 3½ miles northwest of Fruitland on the Jewett-Durango road, the coal bed is 23 feet in thickness, and is practically all good coal. Recently this mine has been acquired by the Southern Pacific Company, which is making surveys for a railroad line through this part of the field.

Including the Bruce mine and surrounding prospects, the workable coal beds at Fruitland seem to underlie an area of not less than 30 square miles.

In the northeastern part of the district coal has been mined at a number of localities near the Colorado State line, on La Plata River and McDermott Arroyo, where it occurs in a single bed 35 feet thick. One of the principal producers at the present time is the Jones mine, 1½ miles northwest of Pendleton. At this mine the strata incline about 25° southeast, and the following section is exposed:

Section of coal bed at Jones mine, 1½ miles northwest of Pendleton, N. Mex.

	Ft.	in.
Coal, with many thin shaly to bony partings	15	
Coal, with three or four shaly partings, varying from one-half inch to 2 inches	33	
Shale		½
Sandstone.		

A sample for chemical analysis was taken at this mine in the usual manner. A cut was made across that part of the bed now worked, which consists of 7 feet of clean coal without a parting. The sample was crushed and quartered down to convenient size and sent in a sealed can to the chemical laboratory. The result, as given in analysis No. 2 on page 258, shows that this is of better quality than most of the coal of the district. The moderate amount of moisture indicates that this is a bituminous coal of nearly the same quality as the coal at the head of Beaver Creek, Colorado, as shown in analysis No. 1, but the greater percentage of fixed carbon would seem to indicate that it is of somewhat higher grade. When the percentages of ash in the two samples are considered, it will be seen that the Pendleton coal is very much better than the Beaver Creek coal.

Proximate analyses of Durango-Gallup coals.[a]

No.	Location.	Stratigraphic horizon.	Thickness of bed mined.		Air-drying loss.[b]	Total moisture.[c]	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel value.[d]	Sampler.
			Ft.	*In.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*	
1	Wheeler mine, at head of Beaver Creek, near Nelson's ranch, La Plata County, Colo.	Laramie?............	3	2½	2.20	4.79	35.04	45.45	14.72	0.77	....	F. C. Schrader.
2	Jones mine, 1½ miles northwest of Pendleton, N. Mex., on La Plata River.	Laramie?............	7		4.60	8.30	35.56	47.89	8.25	.67	....	F. C. Schrader and M K. Shaler.
3	Young mine, 1½ miles northwest of Fruitland, N. Mex., on San Juan River.	Laramie?............	5		4.50	9.89	38.44	41.48	10.19	.64	6,276	F. C. Schrader and M. K. Shaler.
4	Clark mine, Clarkville, N. Mex.......	Upper coal group [Montana].	8	6	9.30	13.95	38.43	42.12	5.50	.54	....	M. K. Shaler.
5	Weaver mine, 3 miles north of Gallup, N. Mex., bed No. 3½.	Upper coal group [Montana].	6	9	....	10.96	42.63	42.39	4.01	.52	6,603	M. R. Campbell.
6	Weaver mine, 3 miles north of Gallup, N. Mex., bed No. 3.	Upper coal group [Montana].	4	1	....	11.77	41.85	43.11	3.26	.54	....	M. R. Campbell.
7	Otero mine, 1½ miles east of Gallup, N. Mex., Crown Point bed.	Upper coal group [Montana].	5	6	....	9.13	40.77	40.23	9.87	1.27	....	M. R. Campbell.
8	Otero mine, 1½ miles east of Gallup, N. Mex., Otero bed.	Upper coal group [Montana].	5	1	....	10.80	40.35	42.77	6.08	1.06	....	M. R. Campbell.
9	Otero mine, 1½ miles east of Gallup, N. Mex., Thatcher bed.	Upper coal group [Montana].	4		....	9.68	41.42	40.82	8.08	1.55	6,457	M. R. Campbell.
10	Tiejen prospect, 17 miles northeast of Thoreau, N. Mex., on Seven Lakes road.	Middle coal group [Montana].	4	9	5.20	15.03	37.26	41.97	5.74	.57	....	F. C. Schrader.
11	Porter mine, Porter, Colo., bed No. 3 (Porter).	Mesa Verde [Colorado].	3		1.30	2.73	36.65	54.48	6.74	.53	7,730	M. R. Campbell
12	Kutz mine, Monero, N. Mex., upper bed.	Mesa Verde [Colorado].	3	5	.90	3.04	39.02	48.28	9.66	3.52	7,185	F. C. Schrader and M. K. Shaler.
13	Rio Arriba Coal Company, Monero mine No. 1, Monero, N. Mex., lower bed.	Mesa Verde [Colorado].	2	9½	1.50	3.99	39.03	51.04	5.94	1.01	....	F. C. Schrader.

[a] Analyses made by F. M. Stanton at U. S. Geological Survey coal-testing plant, St. Louis, Mo.

[b] After being crushed to one-fourth inch the sample was exposed to the air in the laboratory for about twenty-four hours, or until the weight became fairly constant. The loss of weight is "air-drying loss."

[c] Includes air-drying loss.

[d] These values can be converted into British thermal units by multiplying by 1.8.

COAL RESOURCES OF THE KENOVA QUADRANGLE.[a]

By WILLIAM CLIFTON PHALEN.

GENERAL DESCRIPTION.

Location.—The Kenova quadrangle of the United States Geological Survey embraces an area of 938 square miles, lying in northeastern Kentucky for the most part, but including small portions of Lawrence County, Ohio, and Wayne County, W. Va. (See sketch map, fig. 10.)

This area lies in the western portion of the great Appalachian coal field and just a trifle north of its center as it stretches from north-central Alabama to the southwestern boundary of New York.

Structure.—The Kenova quadrangle is located at the southwest end of the great trough into which the coal-bearing rocks of the Appalachian field are thrown. The axis of this trough extends from the vicinity of Pittsburg, Pa., to the southwest, reaching its maximum depth near central West Virginia. From this point it slowly rises to the southwest, crossing Ohio River a little east of this quadrangle and reaching Big Sandy River near the mouth of Isom Creek, opposite Burgess (Kavanaugh), Ky., and extending in a general southwesterly direction from this point, gradually fading as the southwestern corner of the quadrangle is approached. Toward this axial line the beds are gently inclined, those on the northwestern side dipping to the southeast and those on the opposite side dipping to the northwest.

The dips in this quadrangle do not average more than 50 feet per mile and in some localities the beds are practically flat. In others there is a marked increase in the dip, as in the region south and southeast of Louisa and from Torchlight to Gallup, where the dips range as high as 150 feet, and even more, per mile. This zone of high dips continues southwest of Louisa up Lick Creek and to the west by Adams post-office as far as the town of Blaine. In the eastern part of this village occur the maximum dips of the region, namely, 11° in a general northwesterly direction. There are higher dips than this near the village, developed locally, however, with faulting, the extent of which will be duly recorded when the field notes have been worked up in detail. Beyond Blaine the abnormal conditions seem to die out, and about a mile up Hoods Creek and also immediately north and west of the town the dips again become normal. In the region to the north and northwest of Willard there are local dips reaching much above the average.

DESCRIPTIVE GEOLOGY.

With the exception of a small area of peridotite[b] near the southwestern border of the quadrangle, in Elliott County, the rocks are entirely sedimentary in origin and belong to the Pennsylvanian series of the Carboniferous system, with the exception of a bare showing of Mississippian (Lower Carboniferous) rocks, the Pleistocene gravel of the river terraces, and the recent unconsolidated sediments of the flood plains. The coals were numbered from below upward by the earlier geologists in the Kentucky field and in the following notes references to numbers are to those of the Kentucky Geological Survey.[a] The Pottsville outcrops generally all over the western and southern portions of the quadrangle, running under drainage toward the syncline and forming most or all of the hills along the western and southern edges of the quadrangle. It is prevailingly sandy. This group of rocks comprises all the coals up to and including coal No. 4, besides valuable beds of fire clay. The base of the formation is easily determined, for it rests on top of the Greenbrier (Lower Carboniferous) limestone. Its top is composed of the usually massive Homewood sandstone, which lies some feet above coal No. 4 or rests directly on this coal bed. Certain of the coal beds of this group of rocks are very important on the edges of the basin in the southeastern and western parts of the quadrangle. It is possible that rocks still lower in the Pottsville than the basal Pottsville beds along the western side of the basin occur in the Levisa Fork district, but the evidence on which this statement is based depends on fossil plants collected by Dr. David White, and these have not been studied closely enough up to the present time to warrant a positive statement on this point.

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[a] These notes are intended as a brief preliminary sketch. A more detailed description of the coal resources of the Kenova quadrangle will be published later.

[b] For a complete description of this interesting occurrence see Diller J. S., Peridotite of Elliott County, Ky.: Bull. U. S. Geol. Survey No. 38, 1887.

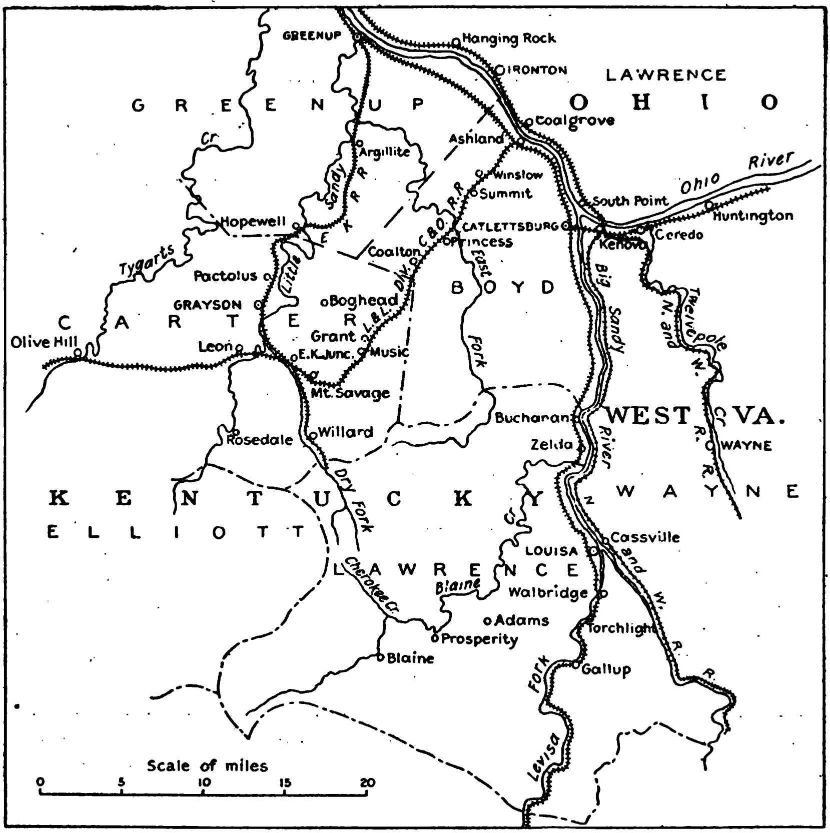

FIG. 10.—Sketch map of northeastern Kentucky and portions of adjacent States.

Above these lower sandy formations occurs the group of rocks corresponding to the Allegheny formation of Pennsylvania and containing coals No. 5 to No. 9. It consists of alternating beds of sandstone and shale, with occasional thin beds of limestone, iron ore, and fire clay. This group includes the celebrated Ashland or Coalton coal and the

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[a] Crandall, A. R. Report on the Geology of Greenup, Carter, and Boyd counties, and a part of Lawrence; Geol. Survey Kentucky, Report on the Eastern Coal Field, vol. C, 1884, pp. 1–78.

"Ferriferous" limestone,[a] with its important associated fire clay. This group may be readily recognized, as it rests on the Homewood sandstone and is capped by a similar massive bed lying above coal No. 9. It is variable in thickness. For example, southwest of Willard it thins from 130 to 90 feet in crossing a hill. Near Coalgrove, Ohio, it is approximately 180 feet thick.

A cut on the Norfolk and Western Railway near the mouth of Big Sandy River displays some of the most massive sandstones in the area. These form the base of the next higher formation. The rocks of this division are prevailingly shaly, usually bright green or red, with occasional beds of sandstone, some of which become very massive, together with beds of limestone and iron ore. This formation includes coals No. 10 and No. 11, and smaller seams up to the base of the Pittsburg coal. It corresponds to the Conemaugh formation of Pennsylvania, and where fully represented west of Centerville, W. Va., is about 300 feet thick. Above the Pittsburg coal occur 100 feet of higher beds belonging to the Monongahela formation.

GENERAL DESCRIPTION OF COAL BEDS.

There are workable beds of coal scattered through nearly the entire geological column as developed in this area, up to and including the celebrated Pittsburg coal at the base of the Monongahela formation. These coals vary widely in character and include most of the varieties of the bituminous class. The bulk belong to the harder bituminous variety, frequently assuming a splinty aspect. They usually break into blocks along charcoal layers, and hence may be classed as semiblock coals. They are unsuitable, in the main, for coking, but give excellent results for steam and domestic purposes. Nearly all bear transportation and stocking well. Coal No. 7, the Ashland or Sheridan seam, has found and still finds a ready market for furnace work. For convenience in reference and with a commercial rather than a scientific point of view, these coals will be described by districts as follows:

1. Big Sandy River.
2 Louisville and Lexington Railroad.
3. State of Ohio.
4. Little Sandy River.
5. Eastern Kentucky Railroad.

BIG SANDY RIVER DISTRICT.

Though not the most important commercially, this district will be described first, since it includes the widest range of coals, comprising the horizons of all the coal beds in the area. It will thus serve as a natural introduction to the following descriptions: From the structure already outlined, it is evident that the lower beds should appear near the edge of the quadrangle, on the north, west, and south. What will probably prove on paleobotanic evidence to be the lowest coals in the area are the four thin seams showing in the section along the Chesapeake and Ohio Railway on Levisa Fork south of Chapman post-office. So far as known, these are not of workable thickness, the average of each being less than 12 inches. The lowest seam of any importance in this district occurs about 80 feet above this lower group and has been designated the "little cannel" coal from the presence in its main bench of a splint band containing sufficient volatile matter to place it among the cannel coals. It has been opened at Torchlight, near the railroad track, both above and below the tipple of the Torchlight Coal Company, where it occurs 140 feet under the Torchlight or No. 3 coal. Just south of the tipple a section shows 19 inches of coal with one-half inch of fire-clay parting near the base. To the north of the tipple 2 to 2½ feet of bright, clean coal containing bands of splint were seen. The northerly dips carry it almost immediately below drainage. On Threemile Creek this coal is workable and has been opened at a few points near Summit. Its horizon is also above drainage on Lick Creek and Left and Right forks of Little Blaine Creek. For the present this coal may be tentatively correlated with the "clod seam" of the Little Sandy River region.

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[a] This name was used by Andrews and other geologists in the reports of the Ohio Geological Survey. and it is accepted for use in this paper in the same sense, but in the final report a geographic name for this bed of limestone will be proposed.

The next higher coal of economic significance in this region, No. 3 of the Kentucky Survey, may be referred to the Mercer group of the Pennsylvania section. This is among the most persistent of the workable coal beds in the quadrangle. As already mentioned, on Levisa Fork at Torchlight station it occurs 140 feet above the "little cannel" seam, disappearing below drainage about a mile from the mouth of Threemile Creek. It is found in the hills south of a line drawn from Torchlight to Prosperity, and has been opened at a number of points on Lick Creek and Right Fork of Little Blaine Creek, showing a rather persistent and characteristic section. This fact, together with its massive sandstone roof and its position, from 120 to 140 feet below the Homewood sandstone, serve to identify it readily. A typical section is that at the Torchlight mine, the three benches of the main body of coal varying in thickness as the seam is traced to the west.

Section of No. 3 coal bed at Torchlight mine.

	Ft.	In.
Massive sandstone roof.		
Shale	15	
Coal		9
Bone		¼
Coal	1	9
Splinty bone and clay		3
Splint		7
Fire clay and coal, forming the floor		8½
	19	¾

The next higher coal, No. 4 of the Kentucky series, is not a very important bed, except in two restricted localities, namely, in the hills east and west of Levisa Fork and in the dividing ridges between Stinson and Straight creeks, Carter County. It usually occurs near the base of the Homewood sandstone, in some cases directly under this horizon, as on Catletts Creek, Boyd County. At Torchlight it is found 55 feet above coal No. 3, where it shows the following section:

Section of No. 4 coal at Torchlight.

	Inches.
Coal, bone, and fire clay, forming roof	19¾
Coal	19
Fire clay	¼
Coal	11-20
Fire-clay floor.	
	59

It will be noted that the main section of coal shows two benches—a condition which exists where the coal outcrops along Lick Creek and also on the Kentucky side of Ohio River near Ashland and Catlettsburg. The Lick Creek coal lies from 70 to 80 feet above coal No. 3 and is the thickest coal observed in the quadrangle. A few sections obtained from openings on the property of the Louisa Coal Company in the divide between Lick Creek and Levisa Fork will well illustrate the character of this seam.

Sections of No. 4 coal on Lick Creek.

I.

	Inches.	
Shale roof.		
Splint and bituminous coal mixed	49	(1)
Fire clay	8	
Soft, bright coal	6	(2)
Bone	5½	
Coal	7½	
Bone	8	
Coal	9½	
	93½	

II.

	Inches.	
Shale roof.		
Coal	13½	(1)
Bone	2½	
Coal	51½	
Bone	2	
Coal	8	
Parting	60	
Coal, reported	36	(2).
	173½	

III.

Coal	65	(1)
Fire clay	5	
Coal	4½- 5	(2)
Bone	8 - 9	
Coal	4½- 6	
Bone	7	
Splint	22	
Fire clay.		
	116-119	

An analysis of coal collected near the outcrop, kindly furnished by Mr. A. C. Collins, of Mount Vernon, Ohio, reveals the following composition:

Analysis of No. 4 coal.

[Otto Wuth, analyst.]

Water	0.97
Volatile matter	32.70
Fixed carbon	55.69
Ash	9.58
Sulphur	1.05
	99.99

This same coal is brought above drainage on the opposite side of the basin near Catlettsburg. A section at a country bank on Catletts Creek is typical of this seam in this region, though the two coal benches are sometimes larger and sometimes smaller than the figures indicated. This section is as follows:

Section of coal underlying the Homewood sandstone on Catletts Creek.

	Inches.
Coal	12
Fire clay	7
Coal	11
	30

The group of coal beds described above is usually overlain by the massive Homewood sandstone, which lies a short distance below the "Ferriferous" limestone. In using this topmost member of the Pottsville formation as a guide, however, discrimination must be exercised, for, though it is most commonly present, it sometimes dwindles to a few feet of shaly sandstone. In the region under discussion the sandstone may be used without danger of error, since it is very thick and massive throughout the Big Sandy River area.

The rocks lying between the Homewood sandstone and the sandstone usually occurring above coal No. 9 are known as the Allegheny formation. In this interval occur the most important and best-known coals of northeastern Kentucky. A section taken at Coalgrove, Ohio, opposite Ashland, shows this formation to be about 180 feet thick.

North of Torchlight, along Levisa Fork, the Allegheny coals descend gradually toward the center of the basin. The lowest coal in this formation is not developed on a working scale in the Big Sandy country, but No. 6, the next higher coal of the Kentucky series and the first seam above the "Ferriferous" limestone, has been spasmodically opened in the hills about Louisa and south of Cassville and measures 16 to 29 inches in the cuts recently made along the Chesapeake and Ohio Railway north of the former town. Its variability and small thickness in this region preclude the probability of its commercial exploitation in the near future. Coals No. 7 and No. 8 are not workable as a rule in the valley of Big Sandy River, while coal No. 9, a relatively unimportant coal in most of the Kenova field, reaches its greatest development in this region. It has been opened along the river from the mouth of Horseford Creek north to Zelda station on the Kentucky side, and from the mouth of Tabor Creek to a point opposite Zelda on the West Virginia side. It averages in the neighborhood of 3 feet, though it attains a thickness of 40 inches in places, as at the bank of Alvin Stewart, opposite Zelda station. At Mr. Frank Yates's bank, a mile southwest of Catalpa, 4 feet of coal were measured, but this is above the average for this seam. At Fallsburg and Yatesville this coal is of workable thickness for local consumption, averaging between 25 and 30 inches. A section just outside of the former village measured 30 inches of coal, with a bony parting of 8 inches near the top.

From Zelda to the region about the mouth of the river the Conemaugh ("Upper Barren") formation stretches back into the country on both sides. From Buchanan to the mouth of Campbell Run the beds are very nearly flat, but northward from this point there is a gradual rise, well shown on the West Virginia side by the massive sandstones at the base of the Conemaugh formation. The succession of coals from No. 9 downward are also well exposed and some of them have been opened on Chadwick, Peterman, and Catletts creeks.

Near the center of the basin, at the top of the hills east of Lett post-office, W. Va., is the Pittsburg coal. This, stratigraphically considered, is the highest important coal in the region, and it marks the base of the Monongahela formation. According to Dr. I. C. White,[a] this is the extreme southwestern limit of this coal bed. It has not more than 100 feet of covering at any point, its roof being shale, capped by 20 feet of massive Pittsburg sandstone. On Mr. James Adkins's property it measures 37 inches in thickness, occasionally reaching as high as 48 and even 54 inches, according to Mr. Adkins. It has also been opened by Mr. Abraham Thacker. Its small area hinders its exploitation except for the local country trade.

LOUISVILLE AND LEXINGTON RAILROAD DISTRICT.

In the Louisville and Lexington Railroad district will be included that area whose natural outlet is over this division of the Chesapeake and Ohio Railway. In this district will also be included the city of Ashland. From the latter point to Mount Savage, Carter County, the workable coals are confined to an interval not exceeding 80 feet above the "Ferriferous" limestone, or "red limestone" ore. Lower and higher coals occur in this area, but they are too thin to be of importance, with the possible exception of coal No. 3, opened in the bed of Little Hood Creek, about a mile west of Ashland. From Mount Savage westward the rapid rise brings up beds as far down in the Pottsville as the Sharon conglomerate.

The first coal above the "Ferriferous" limestone, for this reason known as the "limestone coal," is generally developed in Boyd County, especially in the hills about Ashland. Here it occurs embedded in massive sandstones about 40 feet above the limestone, as is also the case on the Ohio side at Coalgrove. It furnishes much of the fuel used in the city, and is utilized by the various brick plants in the eastern part of the town. At Winslow it has been extensively developed, and was mined and coked by the Ashland Iron and Mining Company up to the time of destruction of their washer. At the present time they are working but one mine, No. 8, and this not to its full capacity, shipping only 150 tons per day to the works in Ashland. This coal has been worked as far south as Princess and it is of workable thickness in the country to the east as far as East Fork of the Little Sandy. It has been opened near Mavity post-office about 25 feet above drainage, but it dips to the south and southeast and soon disappears below water level. It does not reappear until the rise of the beds on the southeast border of the basin brings it to light near Louisa.

Where developed most extensively, as in the region about Ashland, the coal appears in three benches, if the small bone streak in the upper portion of the bed be considered a legitimate stratum for division. This trifold character has also been noted on Keyes Creek and at the mines at Winslow. At the latter place the two upper benches are hard and resistant, owing to the admixture of splinty layers, but the lower bench is so soft as to crush when left in pillars. Although an excellent steam and domestic fuel, it has not been found suitable for coking purposes. The following section was measured at No. 8 mine, at Winslow:

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[a] Rept. West Virginia Geol. Survey, vol. 2, 1903, p. 191.

Section of No. 6 coal at Winslow.

	Ft.	in.	
Sandstone roof.			
Bone		5	
Splint coal	1	6	(1)
Bone		1	
Coal	1	6	(2)
Fire clay		3	
Coal	1±		(3)
Fire clay (2 to 3 feet).			
	4	9	

The second bed above the red limestone ore, 30 to 40 feet above the "limestone coal," is the Sheridan or Coalton coal, No. 7 of the Kentucky Survey and No. 6 of the Ohio Survey. This coal has been known and worked for many years in the Hanging Rock region, as this part of Kentucky and Ohio is sometimes called. According to the Ohio Geological Survey reports[a] it is to be correlated with the "great vein," or Nelsonville and Straitsville coal of the Hocking Valley. Up to the present time it has proved by far the most important commercial coal in this area and, though much of the available coal above drainage has been removed along the railroad from Princess to Music, the great mass of the coal lying below drainage in the basin to the east has not been touched. It is found in the hills on both sides of the railroad from Music to Mount Savage, the rise of the rocks to the west, however, soon carrying its horizon above the hills. At the head of Davies Branch it is mined and shipped by the Straight Creek Coal Company, where it has a section indicated by column 3 in the table below. One and one-third miles to the east it is below drainage. Between Princess and Winslow this coal has been extensively utilized for domestic purposes, nearly every farm having had its individual bank at sometime or other, but in the Flatwoods country, between Winslow and Ashland, the hills rise barely high enough to reach it, though beyond Ohio River it again resumes its importance. To illustrate the uniformity of this coal the following sections are appended:

Sections of coal No. 7.

	1.	2.	3.	4.	5.	6.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Coal	4	0 -26½	8	0-18	....	....
Parting	5¼	3	4	6	5	12
Coal	22	21½	24	22	24	18
Parting	2	1	1	1	¼- 1	....
Coal	13½	18 -23	15	22	26	12
	46¾	43½-75	52	51-69	55¼-56	42

1. Section at Eastern Kentucky Railroad mine, east of Willard, Carter County, Ky.
2. Morning Glory Coal Company's mine, Grant, Carter County, Ky.
3. Straight Creek Mining Company, head of Davies Branch, Carter County, Ky.
4. Ashland Iron and Mining Company, mine No. 10, near Rush, Boyd County, Ky.
5. Princess Land and Mining Company's mine, Princess, Boyd County, Ky.
6. Country bank near mouth of Belle Trace Creek.

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[a] Rept. Ohio Geol. Survey, vol. 3, pt. 1, 1878, pp. 917-918.

In general, the roof of this coal is sandstone, while the partings may be either bone or fire clay.

OHIO DISTRICT.

The geological section in the hills of Ohio opposite Ashland is really a continuation of that on the Kentucky side. Both coals Nos. 6 and 7 are of importance and both have been worked. At the present time coal No. 6 is being mined at Coalgrove and shipped to Portsmouth, Ohio. Nothing on a commercial scale has been attempted within the last thirty years on the next higher or Sheridan seam, though much valuable unworked coal remains above drainage in the western two-thirds of Perry Township.[a] The next higher coals in the series, the No. 8, or Hatcher seam, and No. 9, are of local importance only.

LITTLE SANDY RIVER DISTRICT.

The Little Sandy district, so far as coal resources are concerned, is coincident with the territory having its outlet to the north by way of the Eastern Kentucky Railroad, for to the west and south, from Leon to Rosedale, Carter County, the coals are too small to be worked except for local country use. In the following paragraphs will be considered those important coals lying in the drainage of Little Sandy River north of the Chesapeake and Ohio Railway.

The Little Sandy country lies well toward the western edge of the basin, and hence the coals occurring in this territory must be the lower seams. All the coals of any importance lie below the "Ferriferous" limestone and above the Greenbrier limestone. The lowest coal in the region is the "subconglomerate seam" developed on Barrett Creek, Carter County, and Canes Creek, Greenup County. It can not have more than local importance, owing to its thinness. At least two coal horizons occur between this "subconglomerate" coal and the so-called "clod seam" of the Argillite region. The latter seam, owing to a thick "clod," or clay parting, has little value except as a local fuel. It has been opened at many points in the hills near Danleyton and Argillite, on Culp Creek and Henry Branch, as well as in the hills near Hunnewell. It occurs on both sides of Little Sandy River, but the easterly dips carry it below drainage as the Louisville and Lexington Railroad is approached. At a country bank one-fourth of a mile west of Danleyton, Greenup County, the following section was measured:

Section of "clod seam" near Danleyton.

	Inches.
Dark shale roof.	
Coal	10½
Bone	5½
Fire clay	12½
Coal	18
	46½

The coal is of the splinty variety and the large number of openings on it indicate that it is highly valued as a local fuel. Coal No. 3, the stratigraphic equivalent of the Torchlight seam of the Big Sandy River region is present in all the hills of this region. In general, it is above drainage on this side of the basin only to the west of the Louisville and Lexington Railroad. At Boghead and Hunnewell this seam contains an important cannel bench, as the following section at Boghead shows:

Section of lower cannel seam at Boghead, Carter County, Ky.

	Inches.
Shale roof.	
Bituminous coal	5
Bone	2
Cannel coal	15
Fire clay	15
Bituminous coal	14½
	51½

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[a] That is, so much of it as is included in the Kenova quadrangle.

This coal is now being mined by the Kentucky Cannel Company at both the above localities and is shipped to Spain, where it is used in the manufacture of gas. Though the seam is found north of Turkey Fork, in Greenup County, it does not appear to carry the cannel layer in this region.

The next higher coal is of workable thickness in certain parts of the Little Sandy country, though generally throughout the quadrangle it has proved unworkable except in the vicinity of Levisa Fork. At Boghead it appears 30 feet above coal No. 3 and about the same interval below the base of the Homewood sandstone. Here it is mined by the Kentucky Cannel Company in conjunction with the seam below, mainly for its cannel bench. A typical section of the upper Boghead coal shows the following structure:

Section of Boghead coal (upper cannel seam).

	Inches.
Shale roof.	
Bituminous coal	7½
Bone	1½
Bituminous coal	11
Fire clay	7¾
Bone	6½
Cannel coal	9
	43¾

Southeast of Boghead, in the hills north of Upper Stinson Creek, some of this coal has been removed by the Lexington and Carter Coal Mining Company, but at the present time these old workings are fallen shut.

REGION TRIBUTARY TO THE HEAD OF THE EASTERN KENTUCKY RAILROAD.

This district includes the territory watered by Little Fork of Little Sandy River, including the Willard district as well as the important field at the head of Dry and Equal forks, and Elliott County.

About three-fourths of a mile southeast of Willard is found the center of a local basin. The beds rise both to the north and to the south from this point. The rise to the north is exceedingly rapid, and coal No. 7, which at Willard is 685 feet above sea level, is more than 900 feet above in the hills just north of Johns Branch. This rapid rise brings up the lowest horizons of the Pottsville group as developed in the western part of the quadrangle. A seam opened at the mouth of Field Branch is a representative of this group. Mr. Walter Field, who has worked this coal, reports 44 inches as an average. The writer measured 37 inches of clean coal at the mouth of Mr. Field's bank and did not reach the bottom of the bed. The coal is splinty, rather dull in appearance, and gives excellent satisfaction as a domestic and steam fuel. These qualities, in connection with its low position in the hill, suggest the possibility of a good body of workable coal. The remaining coals in the Pottsville series in this territory are rather thin, though in many instances they thicken to respectable proportions and are worked for local use. This is true of coal No. 3 on Dry Fork, measuring 30 to 36 inches, and coal No. 4 on Hilton Branch, showing a bench of cannel of 26 to 29 inches, with 4½ inches of bituminous coal above and massive Homewood sandstone serving as a roof.

The interval from the Homewood sandstone to the "Ferriferous" limestone is variable in this region, as it is throughout the quadrangle. At Willard the interval is about 35 feet, while at the head of Cherokee Creek it is not more than 10 feet. At this locality the lowest coal in the Allegheny formation is well developed on the land of Mr. J. A. Young. This seam, No. 5 of the Kentucky reports, rests directly upon the massive Homewood sandstone and is but a few feet below the "Ferriferous" limestone. Its analysis and section serve to place it among the valuable coals in the region, while the territory occupied is fairly extensive, including the hills at the heads of Dry and Equal forks, Perkins Branch, and Cherokee Creek.

Section of coal No. 5 from Young bank, at the head of Cherokee Creek, Lawrence County, Ky.

	Inches.
Coal	4
Shale and bone	12
Splint coal	8½
Lustrous coal with splint layers	50½
Bone floor.	
	75

According to an analysis made by the Kentucky State chemist, a sample from the Young mine shows the following composition:

Analysis of coal No. 5 from Young bank.

Moisture	7.04
Fixed carbon	53.72
Volatile matter	36.88
Ash	2.36
	100.00

It is probable that this is the same coal which makes such an excellent showing well up in the hills north and south of Johns Branch.

Coal No. 7 maintains its importance in this region, and has been mined at Willard and as far south as Webbville. Several country banks are working this coal on Belle Trace Creek and at Partloe. At the latter place the Eastern Kentucky Railroad is utilizing the coal for use in its engines and for shipment to various points along its track. Sections of this coal from a country bank on Belle Trace Creek and from the mine at Partloe have already been given (see table, p. 265).

DEVELOPMENT OF THE BEAR CREEK COAL FIELDS, MONTANA.

By Cassius A. Fisher.

Introduction.—During the field season of 1903 a preliminary examination was made of the coal deposits of the Bighorn basin in northwestern Wyoming. At the close of this investigation, for the purpose of comparison, the writer made a brief examination of the Bear Creek and Red Lodge coal fields, which lie next north, in the southern part of Montana. Coal has been mined extensively at Red Lodge, Mont., for a number of years, but it is only recently that attention has been directed to the extensive development of the Bear Creek deposits. In view of this proposed development the Bear Creek deposits were revisited at the close of the last field season and additional data obtained regarding the character, thickness, and stratigraphic position of the coal beds and the present plans for development.

Previous work.—The first investigations in this field were conducted by Mr. J. E. Wolff, of the Northern Transcontinental Survey.[a] W. H. Weed, of the United States Geological Survey,[b] has since described these beds, in connection with other coal deposits in Montana, and a brief statement of the nature of the deposits was published by the late G. H. Eldridge.[c]

Location and extent.—The Bear Creek coal district occupies the highland lying at the base of the Bear Tooth Mountains in the southwestern part of Carbon County, Mont., near the headwaters of Rocky Fork, a small tributary of Yellowstone River. The area underlain by coal is about 3 miles wide and extends in a northwest-southeast direction, the limits of which have been only indefinitely determined. On the south these coal-bearing beds probably do not extend to the Wyoming State line, and to the west of Red Lodge they are covered by a considerable thickness of a more recent formation.

Stratigraphy.—The coal of the Bear Creek district occurs in the upper part of the so-called Laramie formation, which here consists of a series of alternations of sandstone, shale, and clay of variable thickness. The shales are dark gray and usually very sandy. The sandstones are lighter gray and often iron stained. They occur in beds 25 to 30 feet thick and are generally sufficiently soft to weather uniformly with the intercalated shales.

Coal.—The coal occurs within a series of beds less than 600 feet thick and in this mass there are at least seven workable coal beds. They vary in thickness from 4 to 10½ feet and comprise a total of approximately 45 feet. These different coal beds are designated as Nos. 1 to 7, beginning at the top. No. 1 has a thickness of 6 feet, with a few thin partings near the middle. No. 2 is 6½ feet thick and is overlain by a dark shale of variable thickness. No. 3 has a total thickness of 10½ feet, with a parting of varying width near the middle. The roof is hard, rendering it unnecessary to timber the rooms and entries. No. 4 is 4½ feet thick and contains a few small partings. No. 5 has a thickness of 4½ feet, with one small parting of bony coal. The roof of No. 5 is composed of massive gray sandstone; the floor of a gray, compact clay. No. 6 has a total thickness of about 4½ feet, but contains a few shale intercalations. No. 7, the lowest in the series, is 8½ feet thick of clean coal. Below this there are several small seams which are not of workable thickness.

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[a] Wolff, J. E., Report on the Rock Creek coal field, Montana: Tenth Census of the United States, 1886 pp. 755 and plates.

[b] Weed, W. H., The coal fields of Montana: Eng. and Min. Jour., vol. 53, No. 20, 1892, pp. 520-522.

[c] Eldridge, G. H., A geological reconnaissance in northwest Wyoming: Bull. U. S. Geol. Survey No 119, 1894, p. 53.

Development.—Coal was discovered in this general region in 1884 and the first opening was made in 1887 at "Yankee Jim Claim," which occupied the present site of the Red Lodge mine. During the two succeeding years the output of this mine was small, but in 1889 shipments were begun and since that time there has been an average annual production of 600,000 tons. This mine is now owned by the Northwestern Improvement Company. While the coal deposits of the Red Lodge district were known to extend to the south and some prospecting had been done in the head of Bear Creek, no material development took place in this field until 1900, when the Montana Fuel and Iron Company opened a small mine and began shipping coal. During the last four years the total product of this mine has probably exceeded 6,000 tons, having a market value of $3.30 a ton. As Red Lodge is the nearest shipping point to the Bear Creek mine, it was necessary to haul the coal a distance of 4 miles over a very hilly road. This materially increased the cost of production and made it necessary to place the coal on the market at a higher price than the Red Lodge coal, which has a shipping value of about $2 a ton.

At present the Yellowstone Park Railroad Company is building a railroad from Bridger, Mont., up Clark Fork Valley and thence up Bear Creek to the mines, a distance of about 25 miles. Two town sites have been laid out along the new line, one at the mines, known as Bear Creek, and another called Belfry, at the mouth of Bear Creek. A large plant is now being built one-half mile west of the town of Bear Creek by the Bear Creek Coal Company, and is to be equipped with all modern appliances for mining coal of this character. The company has about 1,600 feet of gangways driven on seams Nos. 2 and 3 and, as a result of this development, several thousand tons of coal are now at the mines ready for shipment. Substantial quarters are being constructed for a large force of miners and the company expects to have a large tonnage of coal ready for shipment when the new railroad is completed.

Four companies have extensive holdings in the Bear Creek fields. They are the Bear Creek Coal Company, the Montana Fuel and Iron Company, the Northwestern Improvement Company (the present owners of the Red Lodge coal mines), and the Anaconda Copper Company, also known as the Amalgamated. Of these companies, only the Bear Creek Coal Company is making preparations to develop, but the Montana Fuel and Iron Company expects to increase its output as soon as railroad facilities are available.

CLEARFIELD COAL FIELD, PENNSYLVANIA.

By George H. Ashley.

Introduction.—Clearfield coal, from Clearfield County, Pa., has long been one of the standard coals for comparison all through the Appalachian region. It is regularly quoted on the eastern markets, and with 70 per cent or over of fixed carbon, 22 per cent of volatile matter, and 8 per cent of waste, it is typical of the highest grade of bituminous coal, especially of the so-called "semibituminous" class. To-day interest in this coal field centers in its present condition and the possibilities of its extension in different directions. This paper is based on recent field work on the Houtzdale, Curwensville, and Punxsutawney quadrangles, which cover nearly all of the southern half of Clearfield County, and include the famous Moshannon coal basin, from which all of the original Clearfield coal was derived. (See fig. 11.)

Structure.—This area is divided into two basins by a broad arch which enters the county from the south between Coalport and Westover, then passes northeastward near McCartney, between Belsena Mills and Boardman, to a point between Wallaceton and Bigler. This arch, which rises and is very broad toward the northeast, lifts the rocks until practically all the workable coals have been removed northeast of Belsena Mills. To the southeast of this arch lies the old "first basin" of the First Pennsylvania Survey, in which occurs the Moshannon coal, while to the northwest lies the "second basin." The coals of this district belong mainly in the Lower Productive Measures, or Allegheny formation, including the beds from the Brookville or Clarion coal up to the Upper Freeport coal. The presence of ten to twelve coals, as against seven at the type locality, the known splitting of both the "D" and the "B" beds, and the limited data over many areas have led to a continuation of the use of the letters as used in this field by the mining men, running from "A" for the Brookville coal to "E" for the Upper Freeport coal. By the use of these letters it is intended to suggest relative position and approximate correlation, without implying exact correlation. The principal coals to which they are applied lie from 40 to 60 feet apart through a vertical space of 250 feet. Of these the most important coal has the relative position of the Lower Freeport coal, or coal "D," on Allegheny River.

Moshannon basin.—The two basins may be again subdivided for purposes of detailed discussion into a number of subbasins, to be treated in order from northeast to southwest. Of these the first is the Houtzdale-Osceola, or old Moshannon basin, including the coal lying in the Moshannon Creek and Beaver Run drainage. This basin lies along and just within the southeastern edge of the county, from a point a little southwest of Houtzdale northeastward. It has furnished most of the coal known on the market as Clearfield coal, and is still supplying a large portion of that coal. The "D," or Moshannon seam, as it is locally known, has a thickness all through this basin of from 4 to 6 feet, running occasionally much over the upper figure and averaging about 5 feet. While the heart of the seam in this basin has already been taken, there is still some coal left around the edges of the basin and in the center, where in the early days tracts of coal slightly inferior in thickness or quality were passed by. These remnants are being rapidly removed by a large number of small shipping mines. There are still a few large mines operating in this field, but apparently on bodies of coal which are fast approaching exhaustion.

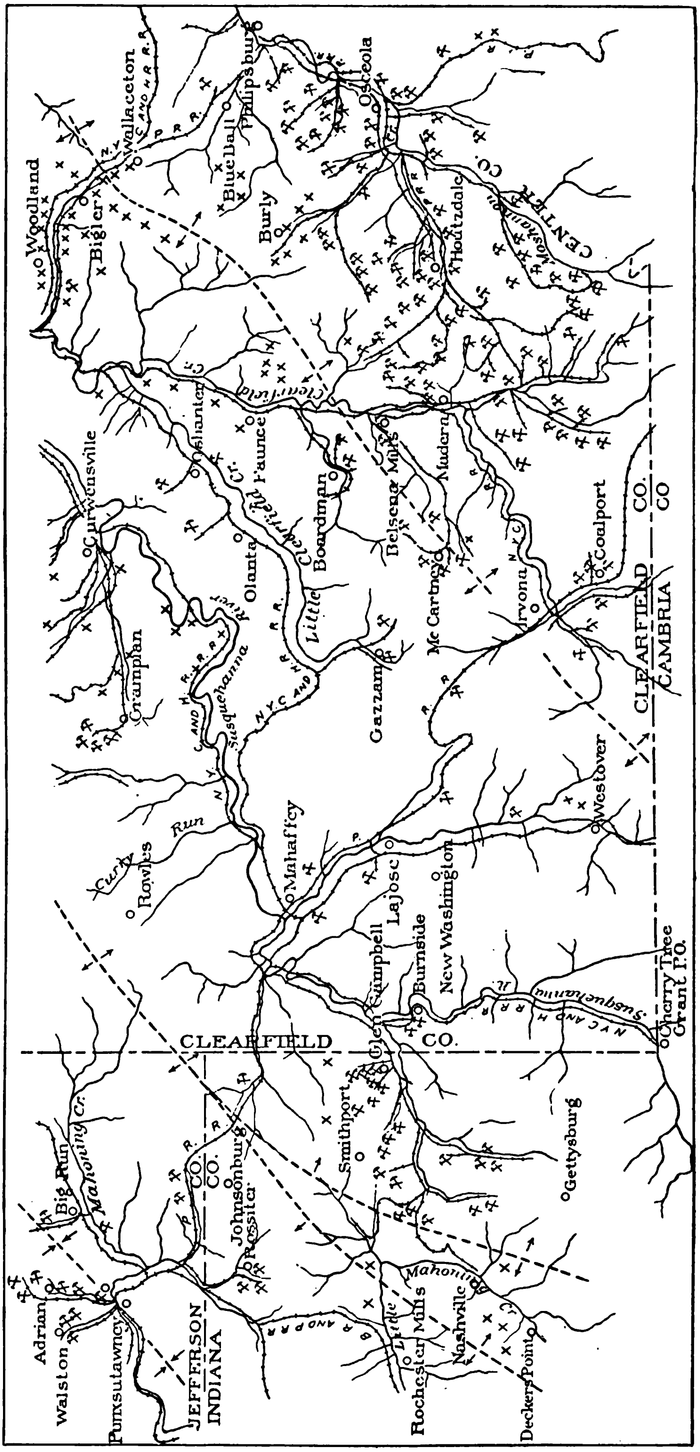

FIG. 11.—Sketch map of southern Clearfield and parts of Indiana and Jefferson counties, Pa. Crossed hammers, coal mines; X, clay mines or outcrops.

The "E," Upper Freeport, or "cap" seam, as it is locally known, is in this basin poorer in quality than the "D" and has a thickness of only 3 feet. At present it is mined only on a small scale. It overlies nearly the same area as the Moshannon seam. Below the "D" seam, coals which are locally workable occur at four different horizons. The first is over 100 feet below, showing 3 feet in places, with a local thickening up to 6 feet or over, due to the presence of several feet of cannel coal. The "B" coal lies about 165 feet below the "D," and shows a thickness of from 2½ to 6 feet. As a rule it is broken up with partings, and tends to carry a larger percentage of sulphur and ash than the "D" coal. This coal often shows three benches, the two upper ones only being worked. The parting is usually bone, but in places is fire clay or sandstone with a thickness of from a few inches up to 4 feet. The middle bench is commonly 3 feet or more thick, and below it is a parting of several feet of hard, knarly clay, then a bench of 18 inches of coal. There is generally a thin rider over this seam within 20 feet. About 220 feet below the "D" coal is the "A" or "A′" seam. While thin in places, this seam may show a thickness of up to 6 feet. Over part of the district it shows two fairly regular clay bands, but generally has many thin, irregular streaks of dirt and is very sulphurous. A seam 30 or 40 feet still lower shows in some of the drillings and in outcrop to the west. This may prove locally workable, though it hardly appears so with the present data. Over a large share of this district the coals below the "D" are below drainage and therefore will present large areas if they prove to maintain workable thicknesses.

Muddy Run district.—The second district includes the coal on the Muddy Run drainage above Banian Junction. It is characterized mainly by the splitting of the "D" or Moshannon seam. West of Houtzdale this coal becomes irregular and locally wanting, but recovers a little farther west, only to split into two benches, which may be as much as 55 feet apart. The lower bench, which alone is mined, at present averages but little over 30 inches thick, but as it maintains the excellent quality of the coal in the first district it finds a ready market and can be worked with profit. This coal appears to run fairly regularly over this whole district. The upper bench and "cap" seam are both thin—2 feet or less. As the lower bench of "D" seam is near drainage in this district, no mining has yet been done on the underlying seams and but little is known of them. Drillings indicate one or two beds below of barely workable thickness in places, though locally there appears to be no workable coal below the lower bench of the Moshannon.

Wallaceton district.—The coals flanking the anticlinal arch to the northeast may be next considered. These districts are characterized by the fact that the lower coals outcrop and are workable, while the "D" coal is absent or of minor importance. In the Wallaceton region the "D" coal is absent, but the "A" and "B" coals are both of workable thickness. The "C" and "C′" coals occur in that region and locally reach 3 feet or more, but generally are under 2 feet in thickness. As they are clean coals, they may be of value in the future. The "A" and "B" coals are very much alike, running from 2 feet 6 inches to 4 feet in thickness, each in two benches separated by a clay parting, which in the "B" coal ranges from 10 inches down, and in the "A" coal from 22 inches down.

Madera-Irvona.—In the region about Madera the "D" coal occurs near the tops of the hills, but has been largely removed. The principal coal of this district occurs about 220 feet below the "D" coal and is designated as the "A" seam, or, since there is a small coal still below it, it may be called the "A′" seam. It shows a thickness of up to 4 or 5 feet of minable coal, but often carries a large amount of cannel-like bone near the top. There is usually one thin parting and occasionally two. The "B" coal of the Houtzdale district has been worked to some extent south of Madera, showing about 3 feet of coal. To the west of Madera the anticline plunges toward the southwest, becoming low enough to carry considerable areas of the "D" coal around McCartney, where this coal is locally 5 feet or more thick. It does not appear to maintain this thickness over any considerable area. Around Irvona and Coalport the "D" coal is unimportant, probably maintaining its split condition from the northeast, while the "B" coal has a thickness of up to 6 feet and will run from 3 feet 4 inches of nearly clean coal to 5 feet. It shows two bony partings, the upper one from a knife edge to 13 inches thick and the lower up to 9 inches thick, dividing the coal into three nearly equal benches. The "C′" and "E" coals in this part of the basin run from 30 inches down, though in a small area west of McCartney the "E" seam shows a thickness of 5 feet of coal, apparently of poor quality, and northwest of Irvona the "C′" coal thickens up locally to 4 feet. The "A" and "C" coals are less than 2 feet thick.

Little Clearfield Creek district.—In the second basin there may be considered first the coal along the Little Clearfield Creek drainage, reached by the Pennsylvania division of the New York Central and Hudson River Railroad. The "D" or Moshannon seam is the coal principally mined in this drainage area. It ranges from 18 inches to 4 feet in thickness, but will average under 3 feet. Its excellent qualities, however, allow its profitable mining even where it does not average over 2½ feet, and the commercial mines have taken coal as low as 17 inches. Around Oshanter it will range from 30 to 40 inches, with one-half inch to 2 inches of shale 5 to 10 inches from the bottom, and it usually carries a bone layer on top. Of the other coals the "E" reaches a thickness of 30 inches in places near Oshanter and on the headwaters of Little Clearfield Creek, but will probably average about 2 feet. The "C" and "C′" coals appear to be less than 2 feet in thickness. The "B" coal ranges from 2 feet 6 inches to 4 feet around Oschanter and 3 feet around Olanta. The "A" coal ranges from 40 to 55 inches near Oshanter, but appears to be less than 2 feet farther upstream. On the whole it appears probable that the "E," "B," and "A" seams will each yield some workable coal. The "E" lies well up in the hills and carries a small body of coal. The "A" and "B" are at or below drainage level and underlie all of this territory.

Grampian district.—The district centering at Grampian lies between West branch of Susquehanna River and the anticlinal arch, running parallel to and 5 or 6 miles north of the river. This region appears to be all underlain by the "D" coal, with an average thickness of 3 feet. West of Grampian and on Cherry Run it locally reaches 6 feet. Most of the sections of this coal show a parting of clay shale or bone from 2 to 8 inches from the bottom. The "E" coal in this district ranges from 18 to 30 inches, averaging less than 2 feet, but is a solid coal. On the arch to the north of McGees it is locally more than 3 feet in thickness. The "C′" coal shows 30 inches without partings near Rowles. The "B" coal yields from 18 to 42 inches, with an average of a little over 2 feet of solid coal. The "A′" or "A" seam shows from 18 to 28 inches of solid coal around Curwensville, but appears to be thinner to the west. On the whole the "D" coal is the important coal of this district, and is probably workable over most of the area of its outcrop. The "B" and the "E" coals may prove to be workable over considerable areas, and the "A" and "C′" coals may be locally workable.

Burnside district.—The southwest corner of the county is included in the upper Susquehanna or Burnside district. The coal mined at Burnside, thought to be the "D" seam, has a thickness of 4 feet 6 inches, with one parting. On lower Cush Creek is a coal, either "E" or "D," showing from 3 feet to 3 feet 6 inches of coal, with a 2 to 5 inch parting 10 to 14 inches from the top. But little mining has been done on the coals of this district, but considerable drilling has been done to determine the character of the coal beds in advance of development. This work has shown that in certain localities no workable coal will be found, while in other localities beds from 3 feet to 3 feet 4 inches lie at distances of between 200 and 300 feet below drainage. North of Burnside the rocks rise so that the Pottsville is above drainage for some distance above and below McGees Mills and up Bear Run. This rise throws the coal beds well up into the hills. It is probable that a large share of this district will yield at least one coal of workable thickness, and locally areas showing two workable coals may be found.

Summary.—It will be seen that according to present information the coals of southern Clearfield County, taken as a whole, are about 3 feet thick, though locally running up to 6 feet. Apparently a large share of this half of the county appears to be underlain by at least one coal bed from 2½ to 3 feet in thickness, most of which, on account of the excellent quality of the coal, may be counted as a source of fuel for the future.

At the present time the largest producers in this field are the Berwind-White Coal Mining Company; Irish Brothers; Peale, Peacock & Kerr; and the Morrisdale Coal Company, each of which mines about half a million tons. There are no very large mines in the area immediately under consideration. None of the mines yields over 200,000 tons a year, and most of them yield less than 25,000 tons. They are practically all nongaseous; the majority of the smaller mines still use the furnace for ventilation, while the larger mines use fans, two of these being of the Capell type. About half a million tons of coal are mined by machine, 74 machines being used in 1903 in 12 different mines. Of these machines 5 are electric and the rest use compressed air. Only a small amount of coke is now produced in this district, amounting to less than 100,000 tons, the largest production being at Irvona, where there are 100 ovens. Seven of the mines make use of 20 electric motors for haulage, and 2 steam engines are used. Most of the mines can not be classed as up to date in their mining equipment, though a few of the large mines, as suggested above, are well equipped.

THE PUNXSUTAWNEY AND GLEN CAMPBELL COAL FIELDS OF INDIANA AND JEFFERSON COUNTIES, PA.

By Frederick B. Peck and George H. Ashley.

INTRODUCTION.

Location.[a]—The Punxsutawney and Glen Campbell coal fields lie just west of the Clearfield County field, which is described in another paper of this bulletin (pp. 271–275). The area discussed is included in the Punxsutawney quadrangle. The Punxsutawney field is of especial interest, as it contains some of the largest coal mines in the United States in point of production as well as the largest continuous bank of coke ovens.

Coals and associated rocks.—The rocks outcropping embrace the lower half of the Pennsylvanian (Upper Carboniferous) series. These include the Allegheny formation, or Lower Productive Measures, with a thickness of from 250 to 300 feet, which carries the Freeport, Kittanning, and Clarion groups of coals. These rocks outcrop over a little less than half of this quadrangle. The rocks between the upper Freeport and Pittsburg coals, of which about 300 feet remain, cover a little over one-half of the area. The Pottsville sandstone, with the Mercer coals, of little or no value, outcrops over limited areas on little Mahoning Creek above Richmond and on Bear Run and Susquehanna River around McGees Mills. The Allegheny formation contains from seven to ten coals, the principal seams being from 40 to 60 feet apart. Some of the area does not contain any workable coal. Much or most of it does not show more than one good workable bed, but sometimes one or more thin beds occur that may be worked in the future. Limited parts of the area contain more than one workable bed. In these fields the letters are commonly used to designate the beds, beginning at the bottom. The correspondence to the coals of the Allegheny Valley is as follows: "A" represents the Brookville, "A′" the Clarion, "B" the Lower Kittanning, "C" and "C′" the Upper and Middle Kittanning, respectively, and "D" and "E" the Lower and Upper Freeport, respectively.

Structure.—The Chestnut Ridge and Richmond anticlines, which enter the quadrangle on both sides of the southwest corner, appear to unite in northeastern Indiana County and to continue to the northeast as a single arch. The Punxsutawney basin lies to the northwest of this arch and the Brush Valley basin to the southeast. The "B" coal, which has an elevation of 2,100 feet on the crest of the arch at the corners of the three counties, has an elevation of 1,050 feet along the axis of the Punxsutawney syncline and lies from 150 to 250 feet below drainage. To the southeast the same coal descends to below 1,300 feet above tide into the Brush Valley basin. On the crest of the arch the rocks lie nearly flat, but on the flanks they dip into the basins at a rate of from 2 to 10 feet in 100. The top of the arch toward the northeast is fairly broad and flat and in that direction is capped by the Mahoning sandstone, which overlies the "E" coal. From the northeast corner of Indiana County toward the southwest erosion has cut down and removed the "E" and "D" coals over much of the crest, those coals occurring only in the high points.

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[a] See map (fig. 11, p. 272) accompanying paper on Clearfield coal field.

THE COALS.

PUNXSUTAWNEY BASIN.

For convenience of discussion the different fields may be given in order, beginning at Punxsutawney. In this basin practically all mining at present is on the "D" coal. The "E" coal, which overlies it at an interval of from 38 to 43 feet, reaches a thickness of 3 feet 4 inches over a considerable area northeast of Punxsutawney, but appears to run out to the east and south. Future mining on this bed will depend on the extent to which the work on the "D" coal has disturbed it. The coals below the "D" are below drainage through most of this basin, and little is known of their thickness and character, but it is claimed that they are not workable. The "D" bed ranges from 4 to 6 feet in thickness, running up to 10 or 11 feet locally. Around Adrian, Walston, and Elk Run it will average about 5 feet 6 inches. Toward Big Run and Eleanora it is thinner, ranging from 4 to 4½ feet, and toward Winslow it thins to less than 4 feet. For a distance south of Punxsutawney all the coals appear to be absent or thin. Around Rossiter one of these coals comes in with a thickness of from 3 feet 8 inches to 4 feet 6 inches, thinning to the northwest and thickening to the southeast. This has generally been called the "E" coal. There is, however, at an interval of 40 feet above it a trace of coal underlain by clay, and that again by limestone, which come directly below what is considered to be the Mahoning sandstone. We have, therefore, considered the Rossiter coal as the "D" coal.

The "D" coal through the Punxsutawney basin is usually free from partings, but in the vicinity of Big Run and Winslow shows 1 or 2 inches of bony coal 10 to 12 inches from the bottom. Over the coal are often from 8 to 9 inches of bony coal. The roof is shale, generally showing a thickness of 12 to 14 feet or more, but in places it is thin and overlain by a sandstone that comes down close to or lies directly upon the coal. Where the shale of the roof is thin it is inclined to be tender, and in places this prevents the use of machines in mining. The floor shows from 2 to 4 feet of clay.

GLEN CAMPBELL OR CUSH CREEK FIELD.

The field work in the region about Glen Campbell has not yet been completed, so that many questions of correllation still remain to be settled. The general facts, however, may be stated at the present time.

Around Glen Campbell and to the northeast and northwest the "E," "D," and "C′" coals are all being worked commercially. Just under the Mahoning sandstone, which north of Glen Campbell is very massive, occurs the "E" coal, which is about 4 feet thick. North and west of Smithport it is often broken up with bony partings. From 18 to 30 feet lower occurs the "D" coal. Locally this shows as two large benches, each broken with partings, giving a total thickness of 16 to 19 feet. These benches will yield from 3 to 6 feet of workable coal. It has been suggested that the "D" and "C′" coals have come close together at this point. Most of the openings around Glen Campbell on the "D" coal show from 6 to 18 inches of bone, or bone and coal, with a lower bench of from 3 to 3½ feet of good coal, having 1 inch of bone a little less than halfway from the bottom. From 30 to 40 feet below the "D" coal is the "C′" coal, which is being worked about Glen Campbell and which there shows a thickness ranging from 4 feet 6 inches to 6 feet, with from 1 to 2 inches of soft bony coal 8 to 12 inches from the top.

Drillings north of Glen Campbell indicate that both the "C" and "B" coals are present in workable thickness. The "C" coal in one drilling is reported as 9 feet thick, but an adjacent drilling showed only 3 feet of coal and rock at the same horizon. The "B" coal appears to have a thickness of from 3 to over 4 feet; still below that are a number of coals, usually not of workable thickness. On the whole, the region close about Glen Campbell seems to yield a large number of workable coals, but these coals are often broken up by partings so as not to be economically minable.

South of Glen Campbell and Smithport, between Susquehanna River and Little Mahoning Creek, nearly all the mining appears to be on one seam, which is tentatively correlated with the "D" coal. It presents a remarkably persistent section. Nearly every measurement made on it shows from 3 to 9 inches of bony coal at the top, in places resembling cannel coal; then a main bench of coal from 3 feet to 3 feet 8 inches thick, a shale parting 1 to 2 inches thick, and a lower bench of coal from 3 to 6 inches thick. The roof is always shale. At most points neither the drillings nor road sections show any coal above that being worked, so that that bed has been widely correlated with the "E" coal. At a few points there appears to be a coal above, and as this coal seems to connect with the "D" coal around Glen Campbell it has been correlated tentatively with the "D" coal, as stated above. The Mahoning sandstone can not certainly be recognized in this area and therefore does not help in solving the problem.

To judge from the openings made on this coal, it will be persistently workable under all of the area within its outcrop south and southwest of Glen Campbell to Little Mahoning Creek, and, as it is below drainage over much of the center of the Glen Campbell basin, it will present a large body of workable coal.

Below this coal there appear to be at least two coals which are locally or generally workable. The first occurs about 50 feet below and shows a thickness of from 2 to over 3 feet. It is a solid coal and has been opened at a few points along the drainage of Little Mahoning Creek. At a distance of from 134 to 178 feet lower drillings show coals which are locally from 3 to 4 feet thick, though some drillings fail to find more than a few inches of coal at these depths. It does not appear certain that these lower coals are all at the same horizon. Tentatively they have been assumed to be such and have been correlated with the "B" coal. The "B" coal outcrops on Hortons Run just west of Glen Campbell and along the valley of Little Mahoning Creek, in both of which areas it shows a workable thickness. Aside from these exposures this bed is below drainage over all of this basin, as well as below the anticlinal arch. If further prospecting, therefore, shows it to maintain a workable thickness, it may be counted on to yield a large amount of coal in the future.

LITTLE MAHONING CREEK DISTRICT.

Under this heading may be considered the coal in the drainage of Little Mahoning Creek from Richmond to Deckers Point. The Pottsville sandstone outcrops in the bottom of the valley between points below Richmond and above Nashville. From 50 to 100 feet above the sandstone through all of this district lies the "B" coal, which locally shows a thickness of over 4 feet to the north of Richmond and of 3 feet in the valley above Nashville. Around Roberts this coal appears to be too thin and broken up to be worked. Just south of Richmond a coal, which appears to be either the "B" or "C," reaches a thickness of from 5 feet to 5 feet 3 inches and is overlain by 5 or 6 inches of bony coal. The "C" coal shows a thickness in the hills southeast of Richmond of from 2 feet 8 inches to 3 feet of coal, with 1 inch of shale 4 inches from the bottom. Above it the "C′" coal has been opened at several points and shows a variable thickness, sometimes as great as 4 feet. The "D" seam appears to have been opened at several points and shows from 2½ to 4 feet of coal, in all cases apparently overlain by a few inches of bone, which locally may thicken to as much as 14 inches. The "E" bed has been opened at a number of points and locally shows 3 feet of coal. In all of this district the data on the coal are so scattered that it can not safely be stated how large bodies may be found of the thicknesses given. From what has been seen of the coal, however, it seems safe to predict that the district will yield a fairly large amount of workable coal, notwithstanding the fact that, owing to the presence of the anticlines, the coals lie high in the hills as compared with the two preceding districts.

DEVELOPMENT.

The Punxsutawney field is characterized by a few large mines rather than many small ones. These mines, if not the largest, are among the largest in the State of Pennsylvania, which places them among the largest in the United States. The Adrian, Florence, and

Canoe Ridge mines all have or have had an output of 3,000 tons or over a day. The Florence and Adrian mines and Elk Run shaft, which are continuous, yielded in 1903 1,708,744 tons; the Walston mines, Nos. 3, 4, and 6, which also connect with the mines just mentioned, yielded over 850,000 tons in 1903; and the Canoe Ridge mine has now an output of about 800,000 tons. The Adrian and Eleanora mines have each produced in the neighborhood of 1,000,000 tons for several years, the Eleanora surpassing that mark in 1899 and the Adrian in 1900. The fact that these mines work all night is an important factor in this production. Of this output the larger portion is machine mined. Thus the Rochester and Pittsburg Coal and Iron Company, out of a total output in this field in 1903 of 3,240,000 tons, mined 2,729,000 tons by machines, using 128 machines for that purpose, all of the compressed-air type. The product of several of these mines goes largely into coke. Of the 2,000 tons a day yielded by Walston mines Nos. 1 and 3, all passing through a 6-inch screen (1,700 tons) is converted into coke. The company has here 657 coke ovens in one continuous row, said to be the longest in the country and to contain also the largest number of ovens. The coal is crushed and sized, then washed to remove the slate and sulphur, after which it is stored in bins to be used in charging the ovens. At Adrian the output is 2,700 long tons daily, or 60,000 tons per month. The coal is a little harder, so that only about one-half of the output passes a 6-inch screen. There are here 511 bee-hive coke ovens, arranged in a double row a mile long. Experience shows that 34,000 tons of coal are required to make 20,000 tons of excellent coke. The large coal is shipped mainly for locomotive use.

Mining in this district is for the most part easy, though at times only fair. Rock rolls and clay veins have interfered with mining in parts of these fields. The use of machines is limited somewhat by the local tenderness of the roof. The machines commonly used are the Harrison, Ingersoll, and Sullivan. Entries in this district are usually 10 feet wide, the rooms 18 to 21 feet, and room pillars 18 to 20 feet. Except the Eleanora and Elk Run shafts, the openings are either drifts or slopes. Capell fans are largely used for ventilation. Most of the mines are troubled with gas. The mines north and northeast of Punxsutawney drain to the Elk Run shaft, in the center of the basin, where the water is pumped to the surface by Cameron, Snow, and Gordon pumps. Both electricity and rope are used for haulage in this district, 2-ton cars being in common use.

The output of the Canoe Ridge mine of the Clearfield Bituminous Coal Corporation at Rossiter is from 2,800 to 3,000 tons daily, most of which goes to the locomotives of the New York Central, Boston and Albany, and Baltimore and Ohio railroads. Robinson and Stein fans are used here. Haulage is by electricity in 1-ton cars. Entries are 9 feet, rooms 21 feet wide, and room pillars 30 feet thick. In 1905 the Buffalo and Susquehanna Coal Company was opening a shaft near Big Run and preparing to operate on an extensive scale. The Jefferson and Clearfield Coal and Iron Company and the Berwind-White Coal Mining Company have each large operations in this field, but outside the limits of the Punxsutawney quadrangle. There are a limited number of smaller operations in this field.

In the Glen Campbell area the mines are uniformly smaller, having a daily output of from 50 to 250 tons, a few exceeding the latter figure. Mines in this district are fairly well equipped, several of them using electric haulage and machines for mining. Furnaces are used in some of the mines for ventilation.

COAL IN SANPETE COUNTY, UTAH.

By G. B. Richardson.

INTRODUCTION.

The report of the State mine inspector for 1904 credits Sanpete County with a production of 6,033 tons of coal, out of 1,563,274 tons mined in Utah. This small amount is furnished by two mines—one near Wales, which supplied only 400 tons, and the other near Sterling. Though the production of Sanpete County is small, the occurrence of coal there is perhaps of more than local interest. Wales claims the distinction of having produced the first coal mined in Utah. Coal is reported to have been discovered there in 1857, and in 1862 this pioneer coal field of Utah was opened. In the early seventies a railroad was constructed from Nephi to Wales, and for a time the coal was taken to Salt Lake City. The Wales coal is of interest because of the unusual occurrence of the deposit immediately between two beds of limestone of Tertiary age, while the Sterling coal is an isolated deposit of Laramie (?) age occurring in a narrow fault block.

Sanpete County is situated in the central part of the State, in the plateau country immediately southeast of the termination of the Wasatch Range at Mount Nebo (see Pl. VIII). San Pitch River, the chief northern branch of the Sevier, occupies a broad valley in the center of the county. The mean altitude of the valley is about 5,200 feet, above which the Wasatch Plateau rises 6,000 feet on the east, while the lower Gunnison Plateau limits the valley on the west. Sanpete County lies just west of Carbon County, which produces most of the coal mined in the State.

GENERAL GEOLOGY.

The plateaus of this part of Utah are underlain chiefly by strata of Mesozoic and Tertiary age, which, except along lines of upheaval, where frequently the beds are sharply tilted, lie flat or only gently inclined. The rocks containing the coals are of Tertiary and Cretaceous age and the valley is occupied by unconsolidated Quaternary deposits. This area is included in the map of the Wheeler Survey[a] and lies immediately north of the region studied by Dutton.[b]

Structure.—Sanpete Valley occupies a north-south structural trough, which separates the Gunnison and Wasatch plateaus. On the western side of the valley a well-defined fault extends along the base of the Gunnison Plateau, the scarp of which rises abruptly above the valley, exposing cross-sections of low, westward-dipping Tertiary strata. Locally the presence of the fault is accentuated by a narrow belt of Mesozoic (?) rocks dipping steeply eastward at the base of the plateau. On the east a monocline of large proportions is well developed. The rocks at the summit of the Wasatch Plateau lie almost flat, but toward the western rim the dip is low to the west and along the flanks increases to 10° or 15°, constituting a dip slope which causes the strata that outcrop on the summit to pass beneath the valley filling. The monocline is broken by several parallel, north-south, normal faults of small dimensions. South of Manti other and larger faults are developed west of the monocline. The Sterling coal lies in one of these fault blocks.

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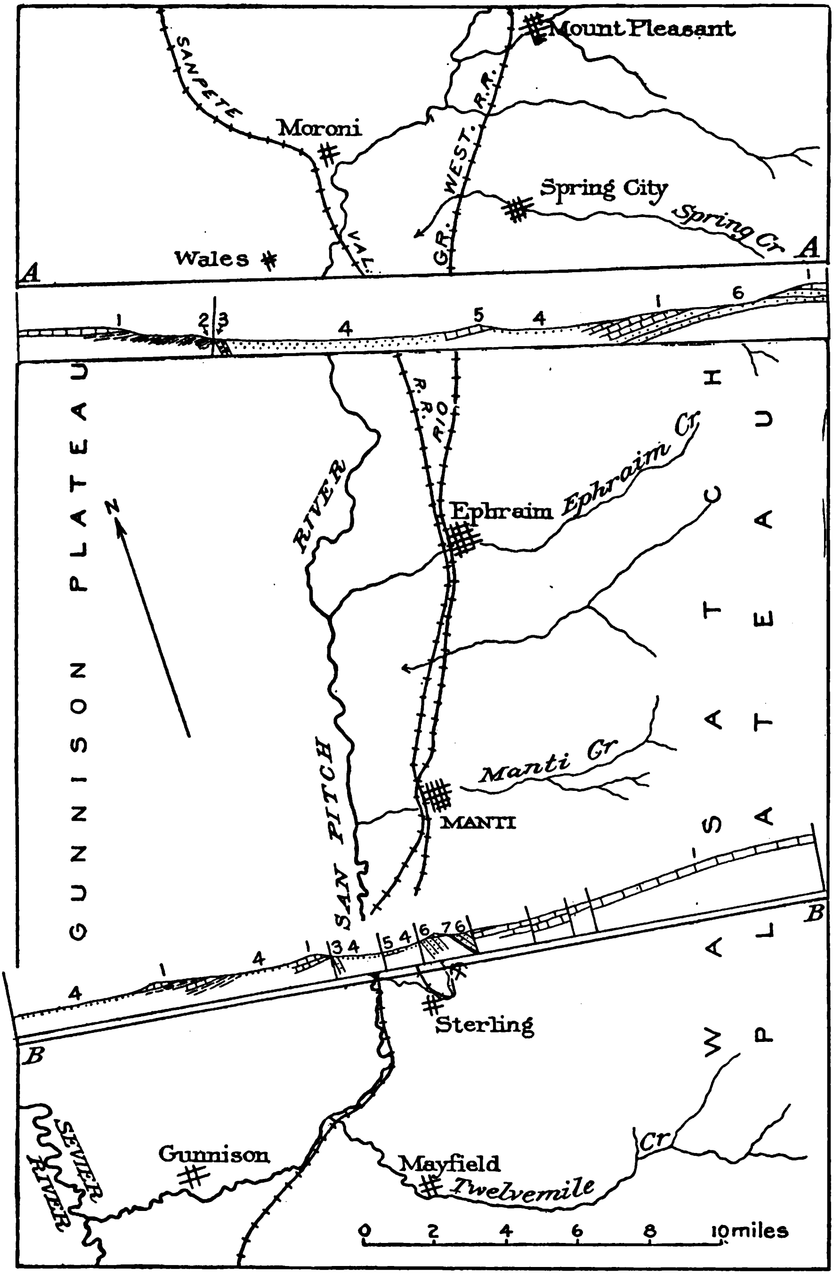
[a] U. S. Geog. Surv. W. 100th Mer., Atlas.

[b] Dutton, C. E., Geology of the High Plateaus of Utah, U. S. Geog. and Geol. Surv. Rocky Mt. Region, 1880.



SKETCH MAP OF PART OF SANPETE VALLEY, UTAH, SHOWING SECTIONS ACROSS THE WALES AND STERLING COAL BEDS.

1, Eocene; 2, coal; 3, Mesozoic; 4, Pleistocene; 5, Manti beds; 6, Laramie; 7, coal.

Stratigraphy.—The oldest rock exposed in the area considered is probably the coarse red conglomerate which outcrops in a narrow belt at the east base of the Gunnison Plateau in the vicinity of Wales. This rock is composed of rounded pebbles of quartzite and subordinate limestone and dips steeply eastward beneath the "wash" of the valley. It is limited on the west by the fault which separates it from the low, westward-dipping Tertiary strata of the Gunnison Plateau. No fossils have been found in the conglomerate, but on lithologic grounds it is provisionally correlated with the great mass of conglomerate west of the Sanpete-Sevier Valley which underlies Eocene and unconformably overlies Paleozoic strata. Its age is probably Mesozoic and possibly may prove to be Cretaceous. This conglomerate is unimportant so far as the coal to be described is concerned.

The coal-bearing Cretaceous rocks of Carbon County outcrop along the eastern scarp of the Wasatch Plateau and are conformably overlain by a considerable but unmeasured thickness of massive buff sandstones which locally cap the plateau, and outcrop in the valleys of the creeks that have cut deeply into its western flanks. This sandstone on the Wasatch Plateau is overlain apparently conformably by fresh-water deposits of Eocene age, but different sections show such variable conditions at the base of the known Tertiary that true conformity in the sense of a succession of widespread, uniform, uninterrupted deposits does not exist. In the vicinity of Sterling there is a distinct unconformity marked by flat-lying Tertiary beds resting on highly inclined sandstones, but here the sandstone is separated from the main mass on the plateau by faulting, and, though probably the same, it is not certain that they are one and the same bed. A few fragments of leaves too obscure for identification are the only fossils that have been found in this sandstone on the plateau, but in the sandstone of the fault block in which the Sterling coal occurs a number of plants have been found, among which F. H. Knowlton recognizes *Sabal* (?) cf. *Sabalites Grayanus*, *Asimina eocenica* (?) Lesq., and *Salix* sp. (?), from which he concludes that their age is probably Laramie.

Tertiary rocks cover the greater part of the area here considered. They outcrop on the summit and western flanks of the Wasatch Plateau and occupy much of the summit and eastern part of the Gunnison Plateau, and also form low ridges in Sanpete Valley. These Tertiary beds are light colored, consisting of drab or locally red shales, with interbedded thin limestone and sandstone layers, and massive, fine-textured, light-gray limestone that weathers white. The stratigraphy is characteristically varied, even adjacent sections being rarely alike. The thickness of the beds is at least 2,000 feet. Numerous fresh-water genera, including *Sphærium*, *Planorbis*, *Physa*, *Goniobasis*, and *Vivipara*, identified by W. H. Dall, occur in these rocks, which are referred to the Wasatch stage of the Eocene.

The Tertiary sediments in the ridges in Sanpete Valley, referred to above, dip slightly to the west and are separated from the Wasatch beds just described by Quaternary deposits. The rocks of the valley undoubtedly are younger than those on the plateau, but whether they conformably overlie the Wasatch strata was not determined. Cope[a] named them the Manti beds and considered their age to be Middle Eocene, corresponding with the Wind River stage. They contain well-preserved specimens of fishes, turtles, etc.

Sanpete Valley is underlain by a considerable but unknown thickness of gravel, sand, and clay, derived from the adjacent highlands and deposited to a large extent at least under subaerial conditions. This valley filling is more than 600 feet thick, as shown by a well near Ephraim.

COAL.

Wales coal.—The Wales coal mine is in Wales or New Canyon, about 2 miles west of the town of Wales, at the foot of the Gunnison Plateau. The coal occurs near the base of the Eocene there exposed, where the following generalized section of Wasatch beds was obtained:

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[a] Cope, E. D., Am. Naturalist, vol. 14, p. 303.

Generalized section of Wasatch beds in Gunnison Plateau, at Wales coal mine.

	Feet.
Fine-textured white limestone	100+
Talus	100
Gray limestone	10
Brown sandstone	10
Talus	150
Brown sandstone	5
Drab limestone	15
Brown sandstone	10
Drab limestone	5
Talus	100
White limestone	10
Drab shale	50
Buff limestone	15
Drab shale	50
Talus	150
Drab limestone	10
Drab shale, with streaks of purple shale	150
Brown sandstone	20
Drab shale, with a few thin beds of limestone	250
Brown sandstone	5
Drab shale	25
Brown sandstone	10
Buff shale	100
Gray limestone	25
Black limestone	5
Coal and bone	7
Black limestone	10
Dark shale	15
Brown sandstone	10
Drab shale	10
Gray limestone	5
Buff shale	40
Sandstone	10

A notable feature of the section is the occurrence of coal immediately between beds of limestone. The limestone itself is black and bituminous and contains abundant crushed shells, including indeterminable species of the fresh-water genera *Sphærium* and *Physa*. At the entrance to the mine, on the outcrop, the following section is exposed:

Section at entrance to Wales coal mine.

	Inches.
7. Limestone.	
6. Coal and bituminous limestone	8
5. Limestone	18
4. Coal including streaks of bone	36
3. Limestone	5
2. Coal and bone	17
1. Limestone.	
	84

No. 2 of this section is rejected. A detailed measurement of No. 4, made in the mine, follows:

Section in Wales coal mine.

	Inches.
Black limestone.	
Coal	10
Bone	2½
Coal	4
Bone	1
Coal	4
Bone	2½
Coal	1
Bone	1
Coal	10
Black limestone.	
	36

A sample collected in the mine by crosscutting the seam was sent in a sealed can to the United States Geological Survey coal-testing plant at St. Louis and analyzed, under the direction of Prof. N. W. Lord, by F. M. Stanton, with the following results:

Analysis of coal from Wales mine.

Moisture	2.17
Volatile combustible	33.50
Fixed carbon	50.94
Ash	13.39
	100.00
Sulphur	4.62
Air-drying loss	.80
Fuel ratio	1.52

This coal has a lower percentage of volatile matter and a greater amount of fixed carbon, and consequently a higher fuel ratio, than the Carbon County coals, but its higher content of ash and sulphur makes it generally less desirable. The coal is too thin and bony to make it very valuable, yet it is used locally for domestic purposes and sells at $2.50 a ton for lump, and $1.80 a ton for fine coal, in competition with the Carbon County product brought to the valley by the Rio Grande Western Railway. The coal has a local reputation for blacksmith's purposes.

The Wales mine is opened on the outcrop and the workings extend about 200 yards along the strike. The coal in the mine dips S. 50° W., magnetic 15°. The mine was dry when visited in August and the operator reported no trouble from water. Apparently the limestone roof is largely responsible for this condition.

This coal can be traced up the hillside north of Wales Canyon for a distance of about 2 miles, where it thins out. To the south it is reported to have been traced somewhat farther, but on account of the varying stratigraphy it is difficult to follow any particular stratum. The development of this mine is comparatively recent. The early workings were in a canyon to the south, but these have long been abandoned. A number of coal prospects occur at different places in the Gunnison Plateau and it is probable that more coal will be found in this vicinity, but it is not likely that much better results will be obtained.

Sterling coal.—The Sterling coal, developed by the Sterling Coal and Coke Company, at the Morrison mine, on Sixmile Creek about 2 miles east of Sterling, is more important than the Wales deposit. The mine is at the southern terminus of the Sanpete Valley Railway. It produced 5,633 tons in 1904.

As already mentioned, the Sterling coal occurs in sandstone of probable Laramie age, in a fault block at the base of the Wasatch Plateau. There are several beds of coal, but only the lower ones could be measured when the mine was visited, in September, 1905. The following section was furnished by H. R. Thomas, the former owner of the mine:

Section in the Morrison coal mine.

	Massive buff sandstone.	Ft.	In.
6.	Coal		22
	Bone and clay		10
	Coal		8
	Sandstone	25–30	
5.	Coal	1	4
	Bone		4– 6
	Coal		6
	Sandstone	75±	
4.	Coal	1	4
	Bone		4– 6
	Coal	1	
	Sandstone	3–25	
3.	Coal	1	
	Bone	1	4
	Sandstone	0–12	

		Ft.	in.
2.	Coal	2	8
	Bone and shale	3	
	Sandstone	3-10	
1.	Coal	1	
	Bone		4- 6
	Sandstone.		

Coal No. 2 is the most important, and locally a bed approximating 4 feet in thickness is formed by the coalescing of Nos. 2 and 3 and the pinching out of the intervening sandstone. The coal is lustrous black. It is much jointed in many directions and breaks easily into small pieces. The principal joints occur in two sets, east-west and north-south, corresponding to the jointing in the adjacent rocks. Thin films of calcium carbonate occur along the joints and small patches of rosin are disseminated through the coal. The ease with which the coal breaks impairs its value, as it results in a large amount of fine coal when it is mined.

A sample of bed No. 2 was collected in the mine by crosscutting the seam with the purpose of obtaining an average and was sent in a sealed can to the laboratory of the United States Geological Survey coal-testing plant at St. Louis, Mo., where it was analyzed by F. M. Stanton with the following results:

Analysis of coal from bed No. 2, Morrison mine.

Moisture	8.07
Volatile combustible	42.59
Fixed carbon	43.20
Ash	6.14
	100.00
Sulphur	.92
Air-drying loss	1.80
Calories	6,537
Fuel ratio	1.01

This is a bituminous coal having a somewhat high amount of volatile combustible matter and therefore a low fuel ratio. The percentage of moisture is rather high and the sulphur is low. At the mine it is reported that the coal will not coke. To judge from the analysis, the Sterling coal is similar to that mined in Carbon County.

Coal was long known to occur in this vicinity, but it was not developed until 1888, when an opening was made on the outcrop above the present workings. About 1894 the railroad was extended to the mine and the coal worked in a slope until so much trouble was caused by water that the mine was abandoned and the present tunnel was made. The mouth of the tunnel is on the hillside along the east bank of Sixmile Creek. It was driven through buff sandstone and thin beds of shale until the coal was struck at a distance of about 2,000 feet. The coal dips from 15° to 20° E.

A copious amount of water has been encountered in this mine, but it is easily drained and the water is transported in a ditch to Manti, a distance of about 6 miles. The water right is a valuable asset. August 17, 1905, the discharge at the mouth of the tunnel was found by C. S. Jarvis to be 5.6 second-feet. It is likely that the water is associated with the fault east of the mine. It probably comes from the westward-dipping sandstone of the plateau region to the east and, being under hydrostatic pressure, rises when it reaches the fault plane. There are a number of strong springs associated with faults in this general region.

The fault plane has not yet been reached in the workings. When it is the coal will be found to be cut off abruptly and its further continuation must be sought by sinking. How far down can not be told, for there is no measure of the throw of the fault

Other occurrences of this coal are limited to the region between Manti and Sterling, for north of Manti the associated strata have been eroded and south of Sterling they are covered by Tertiary beds. The best coal appears to be confined to the area already exploited and seems to be a local deposit. Only thin beds have been found in the valleys immediately north and south of the present workings.

NOTES ON THE WEBER RIVER COAL FIELD, UTAH.

By Joseph A. Taff.

PRELIMINARY STATEMENT.

For many years coal has been worked with varying profit at a number of localities in Weber River Valley and its tributaries, Chalk and Grass creeks, in the vicinity of Coalville, Summit County, Utah. Summit County is in northern Utah and adjoins southwestern Wyoming.

The Weber River coal field is situated east of the Wasatch Mountain range. The river collects its waters chiefly from the northwestern slopes of the Uinta Range, flows northward across Summit County, and thence westward through the Wasatch Range to Great Salt Lake west of Ogden.

Facilities of transportation for the coal of the Weber field are afforded by the Union Pacific Railroad. The main line of this road follows the valley of Weber River from Ogden to Echo, where it turns toward the northeast up Echo Canyon. From Echo the Park City branch of the Union Pacific continues up the Weber Valley through Coalville. From the Park City branch spurs have been constructed to the Wasatch and Grass Valley mines, 2 and 7 miles, respectively, northeast of Coalville. The Dexter mine, the only other one now in operation, is situated 1 mile southeast of Coalville.

The rocks at Coalville were examined and the occurrence of coal noted[a] by F. B. Meek and E. Englemann in 1859 while attached to the exploring party in command of Capt. J. S. Simpson, U. S. Army. Meek revisited the field in 1872 and it was later studied by members of the Fortieth Parallel Survey; also by C. A. White in 1877. Beginning with the Meek and Englemann report in 1860, the rocks were classed in various groups of the Cretaceous. T. W. Stanton has surveyed the Coalville section, besides various others in the western Cretaceous areas. In a comparative study[b] of the Colorado group of the Cretaceous, the coal-bearing rocks of Weber River Valley are included by Stanton in the lower or Bentou division of the Colorado group.

The Weber River coal strata are of the same age as a part of those of the Kemmerer field in southwestern Wyoming, recently surveyed by A. C. Veatch. The exact stratigraphic correlation of the coal beds in the two fields, however, has not been determined.

SURFACE FEATURES.

The larger physiographic features of the country in the region of Coalville are not dependent for their expression on the lithologic character of the formations. The main valleys and ridges cut indiscriminately across the hard and soft rocks. Weber River has a course west of north and Chalk Creek runs nearly west, while the strike of the rocks is generally northeast and southwest. Within a range of 6 miles from Coalville the surface rises 3,500 feet toward the southwest. Toward the east and northwest it rises to elevations of 2,000 and 2,500 feet above the valley of Weber River, which is here 5,600 feet above the sea.

The thicker and harder sandstones of the coal-bearing section, Nos. 1, 4, and 6, given below, and another referred to near the top of the Cretaceous system in this field make distinctive ridges and benches in the lower slopes of the valleys of Weber River and Chalk and Grass creeks. The dip of the rocks is toward the northwest and the outcropping edges of these sandstones make precipitous southeastward-facing cliffs. The lowest sandstone, No. 1 of the section, is less prominent in its topographic effects than the others, yet is a distinct marker for the position of the most valuable coal bed in the field, which lies immediately beneath it.

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[a] Proc. Acad. Nat. Sci. Phila., vol. 12, 1860, p. 130.
[b] Bull. U. S. Geol. Survey No. 106, 1893.

STRATIGRAPHY.

The rock formations consist of shale, sandstone, and conglomerate, with occasional strata of limestone and three or more beds of coal. The numerous faults that intersect the rocks and the spaces of concealed strata in the valleys prevent the measurement of an accurate section in the vicinity of Coalville except by a detailed survey and a careful study of the fossils. Little note was taken of the rocks below the lowest known workable coal now being developed at the Wasatch mine, 2 miles northeast of Coalville. Stanton, who has studied the section at Coalville, reports[a] that below this coal are 500 to 600 feet of interstratified shale and sandstone. The following general estimated section, based in part on Stanton's measurements, in ascending order, will give some idea of the lithologic succession and positions of the coal beds:

General section of coal-bearing rocks in Weber River field.

		Feet.
1.	Wasatch coal, being mined at Wasatch and Grass Valley mines	9- 14
2.	Sandstone, thick-bedded, light gray This sandstone is the roof of coal in Wasatch and Grass Valley mines.	40
3.	Blue-clay marl (Grass Valley) Crops in valleys chiefly and is usually only partially exposed. Coal occurs in the upper part or probably at the top of this shale. It is reported by Mr. Samuel Clark, superintendent of the Wasatch mine, to be a double seam, each bench being 3 to 4 feet and separated by 2 to 3 feet of shale. The upper coal is succeeded by sandstone.	400-765
4.	Sandstone and conglomerate In Grass Valley it appears thicker than at Coalville and is separated into two members by shaly strata.	100-300
5.	Shale and thin sandstone A bed of shell limestone occurs in upper part and a thin bed of coal is reported to occur near the same position in the section. A coal in the upper part of this group of strata, once mined 2 miles southwest of Coalville, is reported by Mr. T. J. Lewis, manager of the Wasatch mine, to consist of two beds, each 2 to 3 feet thick, separated by shale varying in thickness from 1½ to 2 feet.	400-500
6.	Massive light-yellow sandstone and conglomerate Above these sandstones and conglomerates there is shale, probably 1,500 feet thick, which is in turn followed by brown and gray sandstone, with minor shale beds, 1,300 to 1,500 feet thick, to the base of the great Wasatch conglomerate of presumably Tertiary age.	100-300

STRUCTURE.

The coal-bearing rocks in the vicinity of Coalville on the north and west are tilted toward the northwest at angles varying generally between 16° and 20°. The rocks also have been broken and disturbed by two systems of faults. One is a system of strike faults bearing northeast and southwest, almost with the strike of the rocks. The other is a system of dip faults at right angles to the first. A fault belonging to the first-mentioned system may be seen northeast of Coalville. It extends from the northern boundary of the city northeastward across the SE. ¼ sec. 4 and the NW. ¼ sec. 3, T. 2 N., R. 5 E. The abandoned coal mine in the SE. ¼ sec. 4 is located near this fault. The rocks on the southeast side of the fault have been dropped with respect to those on the opposite side. The massive sandstone in the ridge lying across sec. 3 above and northwest of the Wasatch mine has been thrown down until it appears to extend 800 feet beneath its counterpart in the prominent ridge one-half mile to the northwest, extending across sec. 4. A dip fault cuts the rocks crossing near the southwest corner of sec. 3. Another fault of this system occurs nearly 3,000 feet northeast of the Wasatch mine. It crosses the township line near the center of the north side of sec. 3, T. 2 N., R. 5 E. This fault has limited operations in the Wasatch mine toward the north. Minor faulting and belts of fractured strata are found frequently in the mines.

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[a] Op. cit.

In Dexter Hollow and at the Dexter mine, 1 mile southeast of Coalville, the rocks dip 16° SE. Between Dexter Hollow and Spring Canyon, 1 and 2 miles, respectively, south-southeast of Coalville, the dips are eastward. As Spring Canyon is ascended eastward 2 miles from Weber River Valley, the rocks are seen to dip successively northward and then northwestward. These observations indicate that a basin-like fold bears eastward from Weber River Valley in the central part of T. 2 N., R. 5 E. Between this fold and the northwesterly dipping rocks at Coalville the structure is anticlinal and the rocks are probably faulted. Exposures of the rocks are insufficient, however, to reveal the character of the structure.

COAL.

There are certainly three and probably four coal beds mined or prospected in the region of Coalville. These coals will be considered in the order of stratigraphic succession and, as it happens, at the same time in the order of economic importance.

Wasatch coal.—The first of these coals may be called the Wasatch coal, from the Wasatch mine, now in operation, 2 miles northeast of Coalville. The coal here has been removed from an area 4,000 feet on the strike by 750 feet in the direction of the dip. The coal is massive, and varies in thickness between 9 and 14 feet. A sandstone bed 40 feet thick forms the roof. The floor is a dense clay, and is underlain by a bed of bony coal, the thickness of which has not been determined. The coal mines in block, is moderately hard, and appears to be a fair grade of the bituminous variety. In the proximity of faults and zones of shearing that are of common occurrence the coal has suffered considerable crushing. In such places it is rendered weak and considerable slack and soft coal is produced.

The same coal is mined on Grass Creek, 7 miles northeast of Coalville, in sec. 18, T. 3 N., R. 6 E. The Grass Creek coal is the same bed as that of the Wasatch mine. Massive sandstone 40 feet thick overlies it. The coal is usually 8 feet thick, but swells locally to 12 feet. In this mine, as in the Wasatch, the coal is much jointed and broken by faults. Water enters the mine freely through the joints and fault fissures, requiring constant pumping. Because of excessive water the pillars are being drawn in the mine preparatory to moving operations one-fourth mile to the southwest.

The outcrop of the same coal follows Grass Creek, and has been mined at a number of localities down the valley, from sec. 18, T. 3 N., R. 6 E., to sec. 27, T. 3 N., R. 5 E., where it is interrupted by a dip fault which displaces the outcrop of the coal toward the southeast. The coal has been mined at seven or more places along Grass Valley within a distance of 4 miles below the Grass Valley mine, but all have been abandoned. The Union Pacific Railroad was the chief operator, but it is reported to have abandoned the work here in favor of better property in the Wyoming field. The Wasatch coal was mined also in the town of Coalville and for a time a mile northwest of town near the strike fault, but these operations have been abandoned.

Dexter coal.—A coal bed is being developed by the Dexter Brothers, 1 mile southeast of Coalville, in the SE. ¼ sec. 16, T. 2 N., R. 5 E. It is presumed by some that this bed is the same as the Wasatch coal, but the identity of the two beds is not proved by surface indications. The section at the Dexter mine seems to be as follows:

Section at Dexter mine, 1 mile southeast of Coalville, Utah.

	Feet.
Sandstone, full thickness not determined.	
Shales, roof of coal, reported to contain fossil shells	4
Coal, upper bed	7
Shale	4
Coal, lower bed	7
Clay shale	4

The upper bench of coal is the only one now worked. The section below this bench is reported by Dexter Brothers to have been proved by excavations beneath the present workings. The coal in the Dexter mine is clear of shaly impurities or tangible sulphur compounds, and the quality appears to be equal to that of the Wasatch coal. The Dexter coal has been mined to a small extent in several places in the hollow below the Dexter mine. The irregularities in the position of the outcrops, as indicated by the abandoned mines and the difficulties said to have been encountered in mining shows that the strata have suffered considerable displacement by faulting.

Other coals.—A double coal bed occurs nearly 400 feet above the Wasatch coal, but is, at the present time, of little economic importance. The coal in each of the two benches is reliably reported to have been mined a mile north of Coalville. Each bench is 3 to 4 feet thick, separated by a shale bed 2 to 3 feet thick. A coal in the stratigraphic position of this bed has been prospected in the north slopes of Grass Creek Valley near the south side of sec. 3, T. 3 N., R. 5 E. A similar double seam of coal occurs stratigraphically about 700 feet higher and 1,100 to 1,200 feet above the Wasatch coal. In the early development of the country this coal was mined 2 miles west of Coalville, in sec. 19, T. 2 N., R. 5 E. It is reliably reported that each of the beds is 2½ to 3 feet thick and separated by 1½ to 2 feet of shale. A coal in the same stratigraphic position was mined also at one time in the NW. ¼ sec. 4, T. 2 N., R. 5 E.

Quality of the coal.—The Wasatch, Grass Valley, and Dexter mines now in operation in the vicinity of Coalville yield a product that has the physical properties of a fair-grade bituminous coal. It is a black block coal of medium hardness. A sample of the Wasatch coal was analyzed by Mr. F. M. Stanton, chemist, U. S. Geological Survey coal-testing plant, St. Louis, Mo. An analysis of the coal at Winterquarters, one of the most extensive mines in the Book Cliffs coal field, was made also. The Book Cliffs field is the most extensive in the State, and the coal has been successfully used both for steaming and domestic purposes and in the production of coke.

Comparative analyses of coal from Coalville and Winterquarters.

	Coalville.	Winterquarters.
Moisture	13.92	8.10
Volatile matter	37.96	40.21
Fixed carbon	43.67	45.91
Ash	4.45	5.78
Sulphur	1.03	.86
	101.03	100.86

The percentage of water in the Coalville coal approaches that often found in the black lignites, the highest grade of so-called lignites. Owing to the abundant mine water occurring in the mines near Coalville and the shattered character of much of the coal, it is possible that a small amount of superficial water was carried in the sample at the time the analysis was made. The physical characteristics, its behavior on exposure in the atmosphere, and its utilization show it to be a bituminous coal well adapted to domestic uses.

Conclusion.—The coals of the Weber River field, other than the Wasatch and Dexter beds, are of little immediate economic value. The interstratified shales, together with the difficulties experienced in mining incident to water and broken strata, have prevented these other beds from competing with the Wasatch and Dexter coals. The Wasatch and Dexter beds are ample in thickness for successful working, and the quality of the product compares favorably with the better grades of bituminous coals of the Rocky Mountain region. The difficulties in the way of large exploitation of these coals are the amount of mine water and the fractured nature of the beds, resulting in the production of considerable quantities of slack.

BOOK CLIFFS COAL FIELD, UTAH, WEST OF GREEN RIVER.

By Joseph A. Taff.

LOCATION AND EXTENT.

The Book Cliffs coal field is in central and eastern Utah. Its south end lies in eastern Sevier County, near the center of the State. From this locality the field bears north-northeast to Price River near Castlegate, in western Carbon County. From Price River it curves to the east for 20 miles and then bears to the southeast, crossing Green River north of the Rio Grande Western Railway. Beyond Green River it turns to the east and northeast, passing into Grand County and thence into Colorado. Only that part of the field limited to Sevier, northwestern Emery, and Carbon counties has been surveyed and hence is included in this report.

The Book Cliffs coal field is relatively narrow, comprising the eastern escarpment of the Wasatch Plateau through Sevier, Emery, and western Carbon counties and the southern face of the Book Cliffs from Castlegate eastward to the Colorado line (see Pl. IX). The lateral extent of the field is governed by the length and depth of the canyons that have been cut into these escarpments. A local variation in width may be noted in a north-south swell of the strata situated near the eastern rim of the Wasatch Plateau in extreme western Carbon and northwestern Emery counties. The mining towns of Clear Creek and Winterquarters are on the northward pitch of this swell. The erosion of Pleasant Valley and the upper part of Huntington Creek Valley have exposed the coals in this uplift. With the exception of Pleasant Valley the canyons cutting the coal-bearing rocks descend from the plateaus out through the faces of the escarpments into the rolling plain of Castle Valley.

The coal-bearing strata descend gradually inward beneath the plateaus from the middle slopes of the front cliffs and pass beneath the drainage line of the canyons and gulches, as a rule within a few miles of the front. Exceptions may be noted in the case of Price River, Huntington Creek, and Gordon, Cottonwood, Ferron, and Muddy Creek canyons, where the coal outcrops extend from 6 to 20 miles into the plateaus. In such instances the field of available coal is considerably increased.

SURFACE FEATURES.

The region of the Book Cliffs coal field is an open country, and from an eminence near the junction of the Wasatch escarpment and Book Cliffs north of Price the observer may comprehend the general physical features of the whole land at a single sweeping view. The desert plain of Castle Valley stretches away to the limit of vision toward the southwest and southeast. Between the arms of the valley toward the south the broad rugged surface of the San Rafael Swell rises in the distance. Along the borders of Castle Valley on the north and west terraced cliffs rise to heights of 1,500 to 2,000 feet. These form the escarpments of the Book Cliffs and the Wasatch Plateau. Between Castlegate and Sunnyside the Book Cliffs Plateau slopes gradually to the north, in agreement with the dip of the rocks to the base of the Roan Cliffs.

Long, tongue-like, flat table-lands and mesas 100 to 200 feet high, capped by the thick sheet of bowlder wash, the remnants of the old valley floor, extend from the bases of the Book Cliffs and Wasatch escarpments out into Castle Valley. At the borders of these table-lands and mesas are fantastically carved terraces and columns. The floor of Castle

Valley and of the lower slopes of the escarpments at its borders is a friable blue-clay marl. The larger streams that flow from the plateaus have worn through the bowlder layer, forming flat box valleys in the soft clay marl. The smaller drainage channels on cutting through the bowlder and gravel surface sink deeply into the marl, producing an extremely rough, bowlder-strewn, badlands type of topography. Before this erosion occurred the old valley floor stood high above its present level and was covered with a thick mantle of bowlders and gravel, which was spread over the plain for several miles from the escarpments.

Beds of sandstone that are locally variable in thickness occur in the shale of Castle Valley 500 to 700 feet below the top of the formation. At the base of the Book Cliffs they are thin and shaly and have little effect on the topography. From Price River westward they increase in thickness rapidly, aggregating more than 100 feet on Gordon Creek. Toward the south they thin to mere bands on reaching Huntington Valley; but still farther south they become thicker, reaching 200 to 250 feet on Muddy and Ivie creeks at the south end of the coal field. These sandstones, occurring as they do in the midst of soft shales, make peculiar and striking features in the topography and from them Castle Valley has acquired its name. Box canyons, many of them impassable, fluted and terraced cliffs, castellated headlands, and perpendicular towers mark their occurrence. Even where the sandstone is thin it serves as a protecting cap to the buttes, and in many places the underlying clay marl stands in perpendicular columnar walls 100 feet or more in height. The soft layers in the marl weather out in parallel bands in the cliffs, leaving the hard layers as projecting ledges. Thus the cliffs simulate rows of gigantic books.

There is a gradual rise of the surface from Castle Valley toward the San Rafael Swell. The rocks beneath the Castle Valley marl consist of pinkish sandstone several hundred feet thick. This sandstone makes the Red Plateau and the western rim of the Swell. In turn, it is underlain by friable arenaceous shale. On cutting through the sandstone the streams have descended rapidly in the soft underlying marl, creating a strikingly rugged and almost impassable country, which extends diagonally across Emery County from the Red Plateau toward the southwest. The main escarpment produced by these sandstones faces east and south toward the center of the Swell. Numerous channels draining into San Rafael River and Muddy Creek have cut by headwater sapping into this escarpment, reproducing in a measure the topography of the Book Cliffs and the Wasatch Plateau escarpments, with even more picturesque effect. Perpendicular cliffs mark the escarpment faces and deep box canyons extend back into the plateau. On the divides and projecting points between the drainage lines near the escarpments there are high pinnacles and rugged towers of pinkish sandstone.

STRATIGRAPHY.

The survey of the Book Cliffs field during the past season had special reference only to the occurrence of coal. Such work as could be devoted to formations contiguous to the coal-bearing rocks was in the nature of a reconnaissance.

The rocks are naturally arranged in thick groups of strata. In each group either sandstone or shale greatly predominates. They contain scant fossil remains, and sufficient information regarding their age has not been obtained to correlate them with similar well-known beds in other parts of the country. The entire section is without doubt Cretaceous, and the principal coal-bearing strata are within the Laramie formation. Further study of the section and detailed areal mapping will doubtless show that the principal groups of strata may be subdivided into smaller units of more uniform lithologic character. For these reasons the formations will not be named, being described by reference to their occurrence.

Shale of the San Rafael Swell.—The lowest formation was noted in a reconnaissance down Muddy Creek southeast of Emery. Only the upper 250 to 300 feet of the formation was seen. It consists of bluish arenaceous shale. From the cliffs of overlying sandstone it could be seen that deposits of the same character make the desert 12 to 15 miles out on the western slopes of the San Rafael Swell.

L-BEARING ROCKS.

Sandstone of the Red Plateau.—Reddish, yellow, and brown sandstone overlies the blue shale of the San Rafael Swell. On Muddy Creek southeast of Emery, where the section was measured, the formation consists of sandstone, shale, and coal, in the following order, from the top down:

Section on Muddy Creek.

	Ft.	In.
Base of Castle Valley shale.		
1. Brownish and yellow sandstone, with some shale interstratified	25	
2. Thin seam of coal.		
3. Shaly sandstone	10	
4. Shale	5	
5. Coal	5	
6. Shale and thin coal	1 to 2	6
7. Yellow, brown, and pinkish sandstone	125	
8. Bony coal, separated into two nearly equal benches by variable bands of bony shale 4 to 14 inches in thickness	4 to 7	9 2
9. Yellowish sandstone	15	
10. Bituminous shale and coal, the coal occurring in two bands of nearly equal thickness	3	
11. Yellow, somewhat friable sandstone, with thin carbonaceous shale in the central part	225	

This sandstone formation makes the bold, rugged escarpment and the Red Plateau, bounding the San Rafael Swell on the northwest side and the north end, respectively. The escarpment grows higher and more rugged northward from Muddy Creek, and for this reason it is believed that the formation becomes thicker in the same direction. The coal, which is of little economic importance, is known to occur only to the east and southeast of Emery.

Shale of Castle Valley.—A blue-clay shale or marl 1,000 to 1,500 feet thick overlies the sandstone of the Red Plateau. Castle Valley is eroded in this shale, and the sandstone lentils in the upper part produce the characteristic topographic features from which the valley derived its name. The lower half of the formation lies in a gently undulating desert plain, and the rocks usually are not exposed. In the coal investigation there was no occasion to examine the lower part of the formation. The upper part, except the sandstone lentils, is an even-textured blue marl that is highly impregnated with alkaline salts. Even on rapidly weathering surfaces the white salts exude in many places. In poorly drained irrigated districts, where the soil is thin, alkaline salts are so abundant as to destroy vegetation. The sandstone lentils that occur 500 to 700 feet below the top are made up of beds of varying purity and thickness. From the vicinity of Sunnyside westward to Price River they are represented by thin shaly sandstone that is scarcely perceptible, having very slight effect on the topography. Westward from Price River the beds increase in thickness, aggregating more than 100 feet in the valley of Gordon Creek. Toward the south the beds thin out to mere bands in a distance of 13 miles. Southward from Huntington they increase again, reaching nearly 200 feet on Quitchupah and Ivie creeks, at the south end of the coal field. The sandstones comprising the lentils include many shaly sandstone and shale beds.

The Castle Valley shale was examined by T. W. Stanton in a brief reconnaissance trip near the Rio Grande Western Railway about 50 miles southeast of Castlegate. The collections of fossils that he was able to make showed that the upper part of the Castle Valley shale belongs to the Montana group of the Cretaceous and that the parting between this group and the succeeding Laramie coincides approximately with the boundary between this shale and the overlying sandstone of the Book Cliffs.

Laramie formation.—The Laramie formation consists of sandstone, shale, and coal in alternate succession. The sandstones occur in beds ranging from a few feet to nearly 500 feet in thickness. For convenience of description the Laramie formation may be separated into three parts—(1) that below the coal, consisting of sandstone and shale in almost equal proportions; (2) coal-bearing series of sandstone, shale, and coal alternately stratified; (3) upper beds, consisting almost entirely of sandstone.

1. The rocks below the coal consist of two thick yellowish to drab and light-gray sandstones separated by a mass of shale and thin sandstone. The lower sandstone varies in

composition as well as thickness. In the Wasatch Plateau it is 80 feet or more thick and generally a massive magnesian sandstone. In the Book Cliffs it is thinner and more shaly. It is always present, however, and is exposed in steep bluffs and often impassable cliffs. This bed invariably overlies the marly shale formation of Castle Valley. Above the lower sandstone is a series of shale and sandstone beds. The sandstone rarely reaches a thickness of 20 feet, and the whole aggregates 60 to 100 feet. These beds are often talus covered. Where exposed they make rather steep terraced slopes, and the sandstone ledges project in benches or low bluffs. Beneath the lowest productive coal bed in the Book Cliffs field there is a continuous sandstone 80 to 100 feet thick. It is light yellow or drab in color except the upper 10 to 20 feet, which is usually white. In the eastern and southern slopes of the Book Cliffs and Wasatch escarpments the sandstone stands out in steep bluffs and often impassible cliffs. In the northern and western slopes of the canyons entering the escarpments it is often broken down, but is rarely concealed by talus. This sandstone bed is a most valuable guide in searching for coal in this region, as it occurs just below the lowest workable coal in the Book Cliffs field. It can not only be traced readily from point to point of the cliffs, but can be recognized at a range of several miles by its characteristic features and position.

2. The coal-bearing rocks consist of nearly equal portions of sandstone and shale, with several beds of coal. With the exception of some heavy beds in the lower part, the series consists of relatively thin strata that are usually more or less concealed by talus. The lowest coal bed where it has been seen fully exposed in mines and prospects varies between 3 and 20 feet in thickness. It rests often directly upon the massive sandstone at the top of the series below the coal. In the localities of its thinner occurrence blue to black shales, usually containing thin coals, occur above it. Where the coal bed is thickest it commonly has a sandstone roof.

Pinkish to yellow sandstone, associated with shale, overlies the lowest coal. These deposits, 30 to 50 feet thick, usually make steep slopes between cliffs of sandstone in the escarpments and canyons that face toward the south and east. In sec. 16, T. 13 S., R. 10 E., north of Price, they are succeeded by a second coal bed 8 feet 6 inches thick.

A massive sandstone overlies this second coal bed. It is yellow to pink in color, except the upper 15 to 20 feet, which is almost white. This sandstone, like that underlying the lowest coal, extends throughout the Book Cliffs field. Its thickness is rarely below 50 feet and sometimes approaches nearly 100 feet.

A third coal horizon occurs immediately above this sandstone in sec. 16, T. 13 S., R. 10 E., where the rocks are naturally displayed for inspection. Fifteen feet of coal were exposed. In Coal Canyon, in T. 13 S., R. 11 E., a coal in this position is 8 feet thick. A coal having approximately the same stratigraphic position in Huntington Canyon, in sec. 24, T. 16 S., R. 7 E., is 8 feet thick. Above this third coal horizon there is a uniform succession of sandstone, shale, and coal, upward for 600 to 800 feet to the top of what is now recognized as the coal-bearing series. It is not usual that the individual sandstone beds exceed 10 feet in thickness. Shales and sandy shales are usually concealed by talus. It is estimated that the aggregate thickness of the shaly beds is nearly equal to that of the sandstones. Several coal beds, some of workable thickness, occur in this series of sandstones and shales. In the Book Cliffs north of Price, between Bull and Helper canyons, one bed occurs 50 feet and another 150 feet above the third coal horizon. In Coal Canyon six coal beds have been exposed in a section of rock 360 feet thick. The uppermost one, 4 feet 11 inches thick and of excellent quality, appears to be above the third coal horizon. In Huntington Canyon and in other places in the Wasatch Plateau coals of workable thickness are known to occur in the upper part of the coal-bearing series, but little attention has been paid to them where coals 4 to 20 feet thick occur lower in the section and are more accessible.

3. The coal-bearing series of shale, sandstone, and coal is succeeded by a formation of light-yellow sandstone that continues upward to the base of the Tertiary deposits in the crest of the Book Cliffs Plateau. Thin coal seams have been seen at a few places in the

lower part of this section and some shale is interbedded with the sandstone in the upper part. The central 500 to 700 feet of this sandstone series make bold cliffs toward the top of the Book Cliffs and Wasatch escarpments. In the Book Cliffs the sandstone is estimated to be not less than 1,000 feet thick. Toward the west it either becomes thinner or is in part concealed by the overlap of Tertiary strata.

STRUCTURE.

That part of the Book Cliffs coal field west of Green River lies on the outer rim, to the north and west, of the broad upward fold known as the San Rafael Swell. The Book Cliffs are on the northward-pitching end of this fold and the rocks dip about 5°. Near the junction of the Book Cliffs and the eastern escarpment of the Wasatch Plateau, at the west side of Price River Valley, the strike of the rocks turns toward the south. Throughout the eastern escarpment of the Wasatch Plateau, from Price River to the south end of the field in eastern Sevier County, the rocks are almost flat. The dips are usually toward the west and rarely exceed 2°.

Folds.—Huntington Canyon and Pleasant Valley cut deeply into the northeastern part of the Wasatch Plateau, exposing the coals and revealing a slight upward flexure of the rocks. The strata have been broadly though slightly warped. The center of this swell is situated near the sources of Huntington Canyon and Pleasant Valley, in western Carbon and northwestern Emery counties. The swell is so low that the westward inclination of the strata due to the San Rafael uplift is succeeded by a horizontal position or one slightly inclined toward the east. The rocks are inclined at a lower grade southward down Huntington Canyon. The dips of the rocks, however, are less than the grade of the stream. The inclination of the strata is very low also toward the west. The dip is very slight toward the north from the head of Pleasant Valley to Scofield. From Scofield northeastward, however, the inclination gradually increases to about 5° in the vicinity of Colton.

Faults.—A series of parallel normal faults, trending in a north-south direction, were noted toward the head of Pleasant Valley; also in Huntington Canyon in the eastern part of T. 16 S., R. 7 E. The fault planes are nearly vertical and the throws or displacements vary from a few feet to nearly 100 feet. Coal prospectors report that greater faults occur on the west side of Pleasant Valley above Winterquarters, but the report was not verified. A few faults of local extent bearing east and west were noted in the Winterquarters mine, and associated with them are parallel thin igneous dikes that locally coke the coal. Another group of normal faults bearing north and south cut the escarpment of the Wasatch Plateau west of Ferron and Emery. In places the faulting is in a single plane, while in others it is compound, resulting in a series of steps or zone of shearing. The block or band of faulted strata west of Ferron and Emery varies from 1½ to 3 miles in width. The largest faults here are on the sides of the block, and the country between them has been depressed downward nearly 300 feet. The fault scarps facing the depressed block at the north side of Ferron Canyon are very pronounced. Conglomerate and shale of supposed Tertiary age occur on this downthrown block at lower elevations than the Laramie sandstone on either side. Several intermediate faults extending parallel to those on the side deform the downthrown block. Some of these minor fault blocks are tilted so that the beds dip as high as 20°.

COALS.

The workable coal beds that have been mined or prospected to any important extent are found in the lower 250 feet of the coal-bearing strata described above. These coals are associated with prominent sandstone beds that can be recognized with ease and assurance by the prospector. They crop out in the lower cliffs and in the more accessible parts of the canyons and valleys.

Quality of the coal.—The workable coals in the Book Cliffs field, with a few exceptions in the thinner beds, have the same physical characteristics, though the beds range in thickness from 4 to 20 feet and in a few instances more than 20 feet. The coal is usually free from shaly impurities and is massive. So pronounced is the massive nature where the coal is fresh that seams or lines indicating stratification are scarcely discernible. It mines in irregular blocks, often of large size. A bed 15 to 20 feet thick is inclined to spall in large irregular slabs several feet in extent across the bedding. The coal is not usually affected nor does it slack to any appreciable extent on exposure to weathering agents. It is black and for the most part has a bright luster. It usually contains small irregular inclusions of a yellowish, brittle, resin-like bituminous substance scattered here and there that yields an asphaltic odor on ignition. The following proximate chemical analyses give a fair idea of the composition of the coals. The samples for analysis were collected from the several beds in the lower part of the coal-bearing section and from localities scattered between Huntington Canyon in the Wasatch Plateau and Horse Canyon, a point 60 miles distant in the Book Cliffs southeast of Sunnyside. The method of selecting samples of coal for analyses is as follows: A clean surface of the whole bed at the face of the working is selected, or a section of about 6 inches in width is made clean by removing the surface. Then a channel 3 to 4 inches in width and of even depth is cut down the cleaned surface, so that an equal amount of coal is obtained for each unit of a section. This coal so removed is placed on a clean surface and immediately broken to lumps half an inch and less in diameter and thoroughly mixed. The sample is then quartered, opposite quarters being taken and remixed. The quartering, selecting, and mixing process is continued until the sample is reduced to about 1 quart, which is placed in a galvanized-iron can, sealed, and shipped to the laboratory.

The Book Cliffs coals are clearly within the bituminous grade, and are remarkably uniform in composition. The sulphur content is also uniform and low, the average being a little above one-half of 1 per cent.

Proximate analyses of coals from the Book Cliffs coal field, Utah.[a]

No.	Location.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Loss of moisture on air drying.
1	Horse Canyon, sec. 4 (?), T. 16 S., R. 14 E	4.76	38.16	52.09	4.99	0.74	1.00
2	Upper bed, No. 1 mine, Sunnyside	3.37	38.04	52.75	5.84	.60	1.30
3	Average of crushed coal, prepared for coking, from all mines, Sunnyside	3.43	37.72	51.68	7.17	.78	1.50
4	Dugout Canyon, sec. 23, T. 13 S., R. 12 E.	4.98	38.20	52.94	3.88	.54	2.40
5	Bean prospect, Coal Creek Canyon, sec. 10, T. 13 S., R. 11 E	4.09	38.06	52.59	5.26	.48	1.10
6	Gilson prospect, Coal Creek Canyon, sec. 3, T. 13 S., R. 11 E	5.42	36.32	52.16	6.10	.54	1.00
7	Western part of Castlegate mine	4.72	39.13	48.45	7.70	.49	1.30
8	Eastern part of Castlegate mine	6.13	40.07	45.45	8.35	.56	3.50
9	No. 1 mine, Winterquarters	8.10	40.21	45.91	5.78	.86	3.90
10	Clear Creek mine, Clear Creek	7.02	41.89	45.80	5.29	.57	3.10
11	Huntington Canyon, Bear Gulch prospect, NE. ¼, sec. 11, T. 14 S., R. 6 E	5.19	43.89	46.91	4.01	.31	2.30
12	Huntington Canyon, near center of S. ½ sec. 24, T. 16 S., R. 7 E	6.04	38.96	48.40	6.60	.83	2.90
13	Larsen Brothers' mine, sec. 2, T. 15 S., R. 6 E	8.46	41.17	46.09	4.28	.48	3.50
14	Emery coal mine,[b] sec. 2, T. 23 S., R. 6 E	5.11	36.71	50.42	7.76	2.06	.80

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[a] These analyses were made by the United States Geological Survey coal-testing plant at St. Louis. F. M. Stanton, analyst.

[b] The Emery coal is in the sandstone of the Red Plateau, 1,500 feet or more stratigraphically below the Book Cliffs coals.

DESCRIPTIONS OF THE COAL BEDS.

Horse Canyon.—A coal bed is exposed in sec. 4, T. 16 S., R. 14 E., near the base of the coal-bearing series. The bed is 14 feet 11 inches thick and is being opened for development. The coal is clean and massive. The floor is a massive sandstone. The roof of sandstone and shale 4 feet thick is succeeded by 2 feet of coal. The same bed was reported to be of equal thickness at prospects in secs. 3 and 9 of the same township.

Sunnyside coals.—Two coal beds are mined by the Utah Fuel Company at Sunnyside, near the mouth of Whitmore Canyon, in sec. 32, T. 14 S., R. 14 E., and sec. 5, T. 15 S., R. 14 E. These coal beds are near the base of the coal-bearing series. The lower coal ranges from 5 feet 3 inches to 6 feet 5 inches in thickness, while the upper bed, 30 feet above, averages about 5 feet 10 inches. Between the two beds are 30 feet of shale, sandstone, and thin coal. The lower Sunnyside coal contains a few thin and locally bony lentils. Its luster is rather dull and it is classed by the miner as "dead" coal. The upper bed is clean and bright. It yields considerable gas on mining and is referred to as a "live" coal. Two mines are in operation here. Both beds are worked from No. 1 mine, while No. 2 mine is confined to the lower. All of the coal is run to a single tipple and is crushed and the entire product coked, the larger part in the coking plant at Sunnyside, the remainder being taken to the ovens at Castlegate.

The composition of the upper coal (No. 2 of the table) is almost identical with the Horse Canyon coal (No. 1). The analysis of the crushed product from all the Sunnyside mines shows a slightly higher percentage of ash and lower proportions of volatile matter and fixed carbon. The ratios between the volatile matter and fixed carbon, however, as indicated in the two analyses, are essentially the same.

Bear Canyon.—A traverse of the Book Cliffs scarp across T. 14 S., R. 13 E., which has not been subdivided into sections, locates the coal prospects of Bear Canyon in the N. ½ sec. 10. Two prospect pits have been dug in the east fork of the canyon, on the coal at the base of the series. The bed has been partially burned near the outcrop and only 4½ feet of coal is exposed in the excavation.

Rock Canyon.—A coal bed 5 feet 10 inches thick is exposed by prospect in the SE. ¼ NE. ¼ sec. 32, T. 13 S., R. 13 E. This coal is near the same horizon as the Sunnyside coal, being probably below the lower bed at that place.

Pace Canyon.—Prospecting has been done in the NW. ¼ NW. ¼ sec. 30, T. 13 S., R. 13 E., where the coal has been burned near the surface. A tunnel has been driven 50 feet on the burned bed, reaching the edge of the fresh coal. Five feet of fresh coal is exposed in another prospect, where the upper part was concealed. These coals are in the lower part of the coal-bearing series.

Dugout Canyon.—The lowest coal bed in this series has been mined by tunnel in the SE. ¼ NW. ¼ sec. 23, T. 13 S., R. 12 E. The bed is 9 feet 6 inches thick and contains a thin bony seam 18 inches below the top. The coal is otherwise massive and clean. Analysis No. 4 above shows the coal to be the equal of any other that has been tested in the Book Cliffs field. Its content of ash, including the bony parting, is the lowest. About 100 feet higher in the section is a second bed showing 5 feet of coal in a shallow prospect. The exposure is at the forks of the canyon, near the center of the NW. ¼ sec. 23. This coal is apparently of good grade, except a thin parting near the top. A third double bed containing 4 feet of coal occurs 200 feet above the first, in a shallow prospect in the north side of the canyon. The parting of shale is 2 feet. One bench of what appears to be the same coal is exposed in the SE. ¼ sec. 23, also in the SW. ¼ SW. ¼ sec. 15. The showing is 2 to 2½ feet thick.

Spring Canyon.—A bed of coal 5 feet 4 inches thick has been opened in the NE. ¼ NW. ¼ sec. 21, T. 13 S., R. 12 E. There is a thin parting in the coal 4 inches below the top. Otherwise the coal is massive. This bed is in the lower part of the coal-bearing series and is believed to be 50 feet above the horizon of the lowest seam.

Soldier Canyon.—Coal has been mined for local use and prospected in a number of places in the central part of the coal series, in the NE. ¼ sec. 18, T. 13 S., R. 12 E. The coal worked is 2 feet 7 inches thick. A lower coal is exposed in the base of the gulch tributary to Soldier Canyon in the NE. ¼ sec. 13, T. 13 S., R. 11 E. This natural exposure shows 4½ feet of coal, but both the upper and lower parts are concealed.

Coal Canyon.—Six beds of coal are exposed in Coal Canyon in the E. ½ NW. ¼ sec. 10, T. 13 S., R. 11 E. Four of these, aggregating 22 feet, are thick enough to work. Three occur in natural exposures and two have been mined. The coal in the lower mine is 8 feet 6 inches thick and its quality is indicated by analysis No. 5 of the table above. It occurs between massive beds of sandstone, each 40 to 45 feet thick. The coal in the other mine, 155 feet higher in the section, is 5 feet thick and its quality is shown by analysis No. 6. There is an intermediate bed, 5 feet 4 inches thick, but it contains a thin parting of bony coal The lowest bed, 3 feet thick, is 200 feet below the lower mine.

Deadman Canyon.—A coal bed 6 feet 10 inches thick has been prospected in the SE. ¼ SW. ¼ sec. 7, T. 13 S., R.11 E. It is estimated to be the same as the lowest bed mined in Coal Canyon. A parting of shale occurs 16 inches below the top. Otherwise the coal appears to be equal to the corresponding bed mined in Coal Canyon.

Cordingly Canyon.—A coal bed 4 feet 3 inches thick has been opened in the east fork of Cordingly Canyon, in the NW. ¼ sec. 14, T. 13 S., R. 10 E. The coal has a shale roof and a massive sandstone floor. It has a bright luster and is clean, but fractures easily, and a considerable quantity of slack is produced in mining. This coal is apparently at the base of the coal-bearing series. A coal bed 14 feet thick occurs 125 feet higher in the section, between a massive sandstone 60 feet thick below and another sandstone 6 to 8 feet thick above. A thin and variable parting of gnarly sandy shale occurs 4 feet below the top of the coal. The coal is massive and lustrous, but breaks readily into blocks in mining, in a similar manner to the lower bed. A short tunnel or drift has been run on this coal in the SE. ¼ SW. ¼ sec. 11.

Ballinger mine.—The basal coal of the series is mined in the west fork of Cordingly Canyon, in the SE. ¼ SW. ¼ sec. 10, T. 13 S., R. 10 E. The coal is 20 feet thick, massive, and moderately hard. It mines for the most part in large irregular blocks. Sandstone occurs in contact both above and below. This coal is mined and transported by wagon for domestic use in the town of Price. Large rooms are excavated and wagons are driven into the face of the working to be loaded.

Wade prospects.—Three coal beds are exposed in the prospects of Wade and Lawley, in the SW. ¼ NW. ¼ sec. 16, T. 13 S., R. 10 E. These coals occur in the lower 160 feet of the coal-bearing series. The lowest coal is the same as that in the Ballinger mine. It is 20 feet thick and massive. It rests directly on a solid sandstone and has a shaly sandstone roof. The second coal, 40 to 50 feet above, is similar in structure and appearance to the first. It is 8 feet 6 inches thick and lies in contact with the sandstone above and below. Of the third coal only the lower 15 feet are exposed. The excavation has not penetrated the weathered coal in the upper part, where the top of the bed is concealed. A thin shaly parting occurs 2½ feet above the base of this coal. The lower coal in this section is exposed in three openings in the west fork of Bull Canyon, near the south side of sec. 9, T. 13 S., R. 10 E.

Panther Canyon.—Two prospects have been driven on the coal at the base of the series in the NW. ¼ NW. ¼ sec. 8, T. 13 S., R. 10 E. The coal has been burned near the surface in this vicinity and the shallow excavations revealed only a part of the coal.

Castlegate mine.—One of the coals near the base of the coal-bearing series is mined at Castlegate. The coal is worked in a series of slopes driven on the rise of the bed toward the south. At the entrance to the tenth rise in the northern part of the mined area the coal is a little more than 4 feet thick. At the face of the coal in the first rise in the southwestern part of the mine the thickness is 6 feet, while in the southeastern part it is 10 feet. At intermediate points it varies between these extremes. The coal is usually massive and clean. The floor is a solid sandstone and lies in low rolls or undulations, being so uneven that mining machines can not be successfully used. The roof is usually sandstone. Thin shales occur locally at the contact of the coal. The quality of the Castlegate coal is shown by analyses Nos. 7 and 8 of the table (p. 294). The mine has been driven through the ridge in places to a fringe of burned coal. The width of the burned area varies and the high temperature of the rock in places where the boundary is approached indicates that spontaneous combustion of the coal probably has not entirely ceased.

Spring Canyon.—The lowest workable coal in the series is opened in two small mines in sec. 9, T. 13 S., R. 9 E. The first, known locally as the Rhodes mine, is near the center of the section in the gulch leading into Spring Canyon. The coal is in three parts and the section is as follows:

Section at Rhodes mine.

	Ft.	in.
1. Sandstone, partially exposed.		
2. Shale	4	
3. Coal, upper bench	1	
4. Shale	1	4
5. Coal, middle bench	1	
6. Shale	3	
7. Basal bench of massive coal, underlain by solid white sandstone	5	

The second exposure, in the NW. ¼, sec. 9, is known as the Pratt mine, and the seam worked at this place probably corresponds to the upper bench of the bed showing in the Rhodes mine, as indicated by the following section:

Section at Pratt mine.

	Ft.	in.
1. Sandstone, partially exposed.		
2. Shale	2	6
3. Massive coal	5	
4. Slope, talus covered, probably shale and lower coal of Rhodes mine	9	
5. Massive white sandstone.		

Pleasant Valley.—Several coal beds have been prospected in T. 12 S., R. 7 E., and some mining is being done for local consumption in secs. 30 and 31. The mine in the NW. ¼ SE. ¼ sec. 30 shows a coal bed 5 feet 10 inches thick that is clear of shaly impurities and of fair quality. This coal is believed to be the same as the coal once mined in the NW. ¼ sec. 31, where a tunnel has been driven through the hill from the Winterquarters mine. On the north side of the canyon, in sec. 31, a prospect shows 4 feet 9 inches of clean coal. A coal bed lower in the rocks and 6 to 7 feet thick is mined near the bottom of the canyon, east of the center of sec. 31. The coal from this mine is used for local consumption in the town of Scofield. A coal bed has been prospected very near the west side of the SW. ¼ sec. 11, and both prospected and mined in the NW. ¼ sec. 13, T. 12 S., R. 7 E. At the first locality the coal is 3½ feet thick, while at the second 3½ to 4 feet of coal is exposed, the base being concealed. In each instance the coal rests on thick white sandstone. This coal is near the top of the coal-bearing series. A coal is mined for local use near the center of sec. 2, T. 12 S., R. 6 E. The bed is 4 feet thick, and the coal seems to be of good quality. It is apparently stratigraphically above the formation recognized as coal bearing in the Book Cliffs field. Prospectors who have worked at Winterquarters and Clear Creek are of the opinion that extensive north-south faults occur on the west side of Pleasant Valley, and that these faults explain the occurrence of coal in the high country in that vicinity. The smooth surface of the country makes it exceedingly difficult to demonstrate the existence of such faults, and without the evidence of definite stratigraphic correlation it can not be asserted that these high coals are to be classed with those occurring near the base of the valley at Scofield, Winterquarters, and Clear Creek.

Scofield.—Mines once operated by the Union Pacific Railroad Company are located one-half mile southeast of Scofield. It is reported on reputable authority that the coal is 25 to 30 feet thick. Only the middle portion of the bed was worked, it is explained, because the coal formed a better roof than the overlying shales. A cave-in has occurred toward the south end of the coal workings, exposing about 30 feet of strata above the coal in the mine, including three beds of coal. The lowest of these beds is 14 inches thick, the middle 5 feet 3 inches, and the uppermost 9 feet. The coal of the two thicker beds appears to be of fair quality.

Winterquarters mines.—Coal is being mined on a large scale in the south side of the canyon at Winterquarters, which is located in the E. ½ sec. 1, T. 13 S., R. 6 E., and the W. ½ sec. 6, T. 13 S., R. 7 E. The coal in mine No. 1 now in operation varies in thickness from 9 feet at the entrance, near the center of the east side of sec. 1, T. 13 S., R. 6 E., to 16 feet at the face of the coal in the southeastern part of the working, near the center of sec. 7, T. 13 S., R. 7 E. The coal is massive and generally clear of shaly impurities. Analysis No. 9 (see table above, p. 294), made from samples selected at the face of the working in the southeastern part of the mine is almost identical with that of the Castlegate coal. The same bed has been worked quite extensively from openings in the north side of the canyon at Winterquarters; also in the south side east of the town and near the center of the W. ½ sec. 6, T. 13 S., R. 7 E.

Two distinct east-west faults were encountered in mine No. 1. Along the one on the north the downthrow is 40 feet on the south and along the other the downthrow is 90 feet on the north. The result is an east-west dropped block a few hundred feet in width. The coal rises toward the south at an angle of about 3° and the downthrown block is overcome in mining by increase in the grade of the slope.

The coal and associated strata in mine No. 1 and in the mine opposite on the north side of the canyon are cut by a number of dikes of basic igneous rocks bearing east and west. The dike in the south mine, nearly 150 feet from the entrance, is approximately vertical, 5 feet in width at the floor and 1 foot at the roof. It swells to a width of 10 feet in the coal bed, which is here 9 feet thick and has metamorphosed the coal, producing a coke-like substance to a distance of 2 to 3 feet on each side. The dike in the northern mine occurs about 300 feet from the mouth of the slope. It is approximately 10 feet thick, and has coked the coal in a similar manner as in mine No. 1. Thin dikes of igneous rock 1 foot and less in thickness are reported by Superintendent Thomas J. Parmley to occur at other places in these mines. Such thin dikes, it is stated, do not metamorphose the coal appreciably.

Crandall Canyon.—A coal bed is mined for local consumption in the SE. ¼ SW. ¼ sec. 13, T. 13 S., R. 6 E., near the head of Crandall Canyon. This canyon leads into Pleasant Valley midway between Scofield and Clear Creek. The coal is approximately 12 feet thick and is massive and clean. It is mined on the rise toward the south.

Clear Creek mine.—This mine is in the town of Clear Creek, near the head of Pleasant Valley. The Clear Creek coal varies in thickness in a north-south direction through the mine working, a length of nearly 7,000 feet. In the southern part the coal is massive and is 13 feet 5 inches thick. No shaly or other impurities were noted. Near the center of the workings a thin shale parting enters the coal. Toward the north and within a distance of 2,000 feet the shale swells to a thickness of 16 feet, dividing the coal into two benches. In the northern part of the mine, where the shaly parting is thick, only the upper bench, 4 to 6 feet thick, is worked.

Several small north-south faults occur near the outcrop, displacing the coal vertically from 5 to 40 feet. Nearly 2,200 feet east of the entrance to the mine a large fault occurs, bearing a few degrees east of north, by which the coal is displaced out of sight. The amount of throw was not determined.

Coal was being prospected in rocks apparently above the coal-bearing series hitherto recognized in the SW. ¼ sec. 31, T. 13 S., R. 7 E., near the head of the gulch bearing west from Clear Creek. The coal bed is about 10 feet thick, and it is regarded by the prospectors as being the same as one of the workable beds found in Pleasant Valley, 1,000 to 1,100 feet lower in the section. The rocks in this region, as elsewhere in the Book Cliffs field, are almost horizontal, and the coal in Huntington Canyon 2 miles southwest of the prospect is near the same stratigraphic position and about the same elevation above sea level as the Clear Creek coal. If the position of the coal near the head of the gulch west of Clear Creek is explained by faulting, as claimed by prospectors, two faults instead of one are required, and it will be necessary to show that a part of the high country between Huntington Canyon and Pleasant Valley is faulted upward a thousand feet or more. Certain thick and distinct sandstone beds, always associated with the lower coals, were not noted in the vicinity of the prospects west of Clear Creek. Rock exposures are less frequent, however, toward the mountain tops than in the lower parts of the canyons.

Miller Canyon.—Two coal beds have been exposed by prospect near the center of the N. ½ sec. 32, T. 15 S., R. 8 E. The lower bed, 10 feet thick, is apparently 25 feet above the horizon of the lowest coal in the Book Cliffs section. The second bed is 4 feet thick and is separated from the first by 5 to 6 feet of shale. The upper coal is overlain by massive sandstone. Near the center of the west side of sec. 20 several beds of coal occur near the base of the coal-bearing rocks in natural exposures. Some of these give evidence of workable thickness, though the coal is disintegrated at the surface.

Cedar Canyon.—The basal coal in the Book Cliffs section has been worked occasionally for a number of years in the north side of Cedar Canyon, in the SW. ¼ sec. 9, T. 16 S., R. 8 E. The coal is 20 feet thick and is separated locally into three benches by variable thin bony and shaly partings. The lower bench, 11 feet thick, is massive and clean. The middle bench is 5 feet thick and the upper bench 4 feet. The coal lies on massive sandstone and is succeeded by beds of thin and shaly sandstone. A tunnel 300 to 400 feet long has been driven toward the north on the lower coal, a short distance west of the present working, in the SE. ¼ sec. 8. The coal in this mine varies in thickness from 16 to 20 feet, and it is reported by one of the operators that no shaly partings were found. The operations in Cedar Creek are conducted by Messrs. Howard & Sons, of Huntington, and they are known as the Howard mine. A coal bed is partially exposed in the north side of the canyon 400 feet stratigraphically above the Howard mine. Several feet of disintegrated coal are shown, but the full thickness of the bed was not determined.

Huntington Canyon.—Systematic prospecting has been done in Huntington Canyon through Tps. 16 and 17 S., R. 7 E. The prospectors confined their attention to the coals in the lower part of the coal-bearing section, and it is reported by the State coal-mine inspector that more than 1,000 openings have been made on these beds.

Twelve or more prospects have been made exposing workable coal beds in Bear Gulch, in secs. 24 and 25, T. 16 S., R. 7 E. Two of the lower coals are exposed on the west side of the gulch, in the northwest corner of sec. 25. The section of coals and associated rocks is as follows:

Section in Bear Gulch, NW. ¼ sec. 25, T. 16 S., R. 7 E.

	Feet.
1. Heavy sandstone.	
2. Shale	1.5
3. Massive coal	10
4. Shale and sandstone, alternating beds; the sandstone at the top makes the floor of the upper coal	40
5. Sandstone	17
6. Shaly roof	1
7. Massive coal	12
8. Massive sandstone; base of lower coal.	

Five other beds of workable coals, aggregating a thickness of 48 feet, are reported independently by two reputable prospectors to have been opened at several places in 300 feet of strata on the east side of the gulch, in the S. ½ sec. 24. Several prospects have been made on some of these coals also in the west half of the same section.

A massive coal bed, 13 feet 4 inches thick, situated near the base of the coal-bearing section, is mined for local use in Deer Gulch, in the NW. ¼ sec. 11, T. 17 S., R. 7 E. A coal bed 3 feet thick has been prospected on the west side of the gulch, near the middle of the east side of sec. 10. This coal is about 175 feet above the coal in the mine.

A coal bed partially burned, exposed in Meeting House Gulch, in the NE. ¼ SE. ¼ sec. 34, T. 16 S., R. 7 E., shows 3 feet of coal. Two beds of coal are opened in three prospects near together in Ridley Gulch, near the northeast corner of sec. 28. The lower of these two beds, 12 feet thick, is at the base of the coal-bearing series and rests on massive sandstone. The other bed, partially burned, occurs 25 feet higher in the section. Five feet of coal are exposed. A number of other prospects have been made on coal farther up the gulch in the same section.

A coal bed 9 feet thick, at the base of the coal-bearing series, has been prospected at the mouth of Trail Gulch, near the center of the NE. ¼ sec. 22, T. 16 S., R. 7 E. It rests on massive white sandstone and is overlain by 4 feet of blue shale. On the east side of the gulch, near the southeast corner of sec. 15, a coal bed 5 to 6 feet thick is exposed. Farther up the gulch, near the west side of sec. 14, two prospects are reported as showing 8 feet of coal. Coals in the lower part of the series have been prospected in many other localities in Huntington Canyon, notably in Mill, Crandall, and Tie gulches, in secs. 21, 16, 5, and 3, T. 16 S., R. 7 E.

Connellville mine.—Coal has been mined at various times for a number of years in Huntington Canyon, in sec. 11, T. 14 S., R. 6 E. The early settlement here was named Connellville. At the present time all habitations are removed except a few for temporary occupation of miners. The coal is mined and hauled to Fairview for domestic consumption. In the only mine now operated the coal is 9 to 11 feet thick. The same bed has been worked at a number of places near the mine and the coal was once coked in a few ovens, now fallen into decay. Several prospects have been made in the vicinity near the base of the series, but they were not open for inspection.

Larsen mine.—A coal bed 8 feet thick is located in the SE. ¼ SW. ¼ sec. 2, T. 15 S., R. 6 E., near the head of the west fork of Huntington Canyon. It is owned and mined at the present time by Messrs. P. A. and L. Larsen to supply domestic fuel for the town of Mount Pleasant. The quality of the coal, as shown by analysis No. 13 (see table, p. 294), is essentially the same as the coals tested from other parts of the Book Cliffs field. The coal occurs between beds of massive sandstone about 350 feet above the base of the coal-bearing series. A bed of coal 3 feet thick is reported by Larsen Brothers to occur about 130 feet below the mine.

Otterson mine.—A coal bed at the base of the series, located very near the south side of the NE. ¼ sec. 26, T. 17 S., R. 7 E., is mined occasionally for domestic consumption at Castledale. The workable part of the bed is 11 feet 10 inches thick, but is divided by a thin parting of shale. The coal seems to be of the average grade of coals in the Book Cliffs field.

Section of coal and associated rocks at Otterson mine.

	Ft.	in.
1. Coal crop, weathered.		
2. Massive sandstone	50	
3. Thin coal seam		
4. Shaly sandstone	10	
5. Coal	1	
6. Shale	1	
7. Coal		8
8. Shale	1	
9. Coal, upper bench	5	10
10. Thin shale parting		
11. Massive coal, lower bench	6	
12. Bony coal	1	
13. Sandstone	3	
14. Sandy shale	4	
15. Massive sandstone	60-80	

Reed mine.—A coal bed near the same stratigraphic position as that worked at the Otterson mine has been opened for local use near the center of the south side of sec. 22, T. 17 S., R. 7 E. The coal is 7 feet 6 inches thick and rests on massive white sandstone. The roof of the coal is a thin bony shale that is overlain by 60 to 80 feet of sandstone. Both the Reed and Otterson mines occur in the cliffs near the heads of gulches leading toward the south, and are approached by steep graded wagon roads.

Johnson mine, Cottonwood Canyon.—The Johnson mine is driven on a bed of coal 7 feet 10 inches thick, situated on the west side of Cottonwood Canyon, in the SW. ¼ NE. ¼ sec. 25, T. 17 S., R. 6 E. The floor of the coal is a massive white sandstone. Shaly sandstone 3 feet thick forms the roof. A coal bed 5 feet thick is reported by Mr. Johnson, the operator of the mine, to occur above the shaly sandstone; also 50 feet higher in the section a bed 3 feet thick is said to have been found. A bed of shale and bony coal occurs 50 to 60 feet below that of the Johnson mine, but it has been proved to be of no value.

Ferron Canyon.—A coal bed 8 feet thick is reported by reputable authorities to occur in Ferron Canyon west of the faulted area in T. 19 S., R. 6 E. This township has not been divided into sections. A traverse up the canyon to the vicinity of the prospect locates it near where the southeast corner of sec. 19 will be placed.

Quitchupah Canyon.—The outcrops of coal-bearing strata in Quitchupah Canyon extend westward into the unsurveyed part of the Wasatch Plateau. A coal bed reported to be 6 to 10 feet thick has been prospected near the base of the coal-bearing rocks in the NE. ¼ sec. 17, T. 22 S., R. 5 E. Another prospect exposing 16 feet of coal is said to have been made in the canyon near the eastern and unsurveyed part of T. 22 S., R. 4 E. Time did not permit an investigation of these prospects.

Ivie Creek Canyon.—Ivie Creek Canyon is situated near the south end of the Book Cliffs field. Coal beds near the base of the series have been prospected on Clear and Red creeks, which flow northward from Mount Hilgard into Ivie Creek; also on Ivie Creek near the mouth of Red Creek. In no instance was the whole thickness of the coal exposed. A prospect on Clear Creek, near the center of the north side of sec. 10, T. 24 S., R. 4 E., showed 6 feet of weathered coal without exposing the base of the bed. A coal prospect on Red Creek, near the north side of the NW. ¼ sec. 3, T. 24 S., R. 4 E., appears to be on the same bed as that opened on Clear Creek. Three feet of the upper part of the bed are exposed in the Red Creek prospect. Two coal beds have been opened in shallow prospects on the north side of Ivie Creek, in the SW. ¼ sec. 34, T. 23 S., R. 4 E. The beds are decomposed and it is believed the exposures do not represent the true thickness of the coal. The upper exposure shows 2 feet, while the lower is 4 to 5 feet thick. The intervening strata consist of 18 feet of shale.

Emery coals.—These beds occur in association with the sandstone that lies stratigraphically below the shale of Castle Valley. They are exposed in the breaks and bluffs of Muddy Creek 4 to 6 miles southeast of Emery. The beds are referred to as the Emery coals since they are utilized to supply Emery with domestic fuel and the town owns the land in which the most valuable mine is situated. A section of the strata including the coals is given above (p. 294), in the discussion of the sandstones of the Red Plateau. Two coal beds of workable thickness were noted. The lower coal is variable both in thickness and in respect to its included strata of bone and shale. A tunnel has been made on the lower bed near the center of sec. 26, T. 22 S., R. 6 E. The coal occurs in two partings separated by 14 inches of shale. The lower workable bench consists of 6 feet of bony coal. The upper layer is 14 inches thick. Across the gulch in which the mine occurs the coal seems to thin out within a distance of one-fourth mile. A coal bed near the same position in the strata crops out in the cliffs on the west side of Muddy Creek Canyon, in the NE. ¼ sec. 35, T. 22 S., R. 6 E. The coal is in three benches and is similar in quality to that at the mine. The lower and middle benches are each 2 feet thick, while the upper is 1 foot 9 inches. They are separated by bands of bony shale 4 to 6 inches thick.

Emery mine.—An upper coal bed occurs 125 to 150 feet higher in the section and within 50 feet of the top of the sandstone series below the shale of Castle Valley. This coal is in a single massive bed 5 feet thick. It is incased in shale and adheres to the roof and floor so strongly that it is separated with difficulty in mining. The coal contains no shaly or bony partings and compares favorably in composition with coals of the Book Cliffs series, as shown by its analysis (see table, p. 294). The mine is situated in the NE. ¼ SW. ¼ sec. 2, T. 23 S., R. 6 E., on the highland west of Muddy Creek Canyon. A drift has been driven 50 feet on the coal and two rooms have been turned.

CONCLUSION.

With the possible exception of one or two coal beds occurring in the high land west of Pleasant Valley all the coals of value known at the present time in the Book Cliffs field are found in the lower part of the coal-bearing strata and near the base of the Laramie formation. At no locality investigated was it found that the entire coal-bearing section had been thoroughly prospected. The beds in the lower part of the series are the more conveniently situated for exploitation and were found usually of ample thickness for profitable working. For these reasons the attention of the prospector and miner has been devoted to them. At every locality investigated for more than 100 miles in the Book Cliffs field coals ranging from 3 to 20 feet in thickness were found where the lower part of the section of the coal-bearing series had been carefully prospected.

The coals in the different parts of the field are remarkably uniform in their physical characteristics. They are black, moderately hard, and usually massive. Occasional shale partings occur in the bed, but one or the other, and sometimes both, benches are sufficiently thick to be profitably mined.

The composition of the coals in various parts of the field and in several beds varies but little, in so far as proximate chemical analyses show. The fuel ratios in the 14 samples analyzed range between the extremes of 1.06 and 1.46. The content of sulphur is remarkably low and uniform. The coking property of the coals has been tested in but few localities, and of these only the coals mined at Sunnyside are known to be coked.

MINERAL RESOURCES OF THE BIGHORN MOUNTAIN REGION.

By N. H. Darton.

GENERAL STATEMENT.

Although in the Bighorn uplift there is an extensive area of the old crystalline rocks, they appear to give but little promise of yielding valuable mineral deposits. Much of the area has been prospected, but only a few claims have been worked to any notable extent, and as yet they have not paid expenses. Gold and copper have been found in small amounts and it is claimed, perhaps erroneously, that platinum was detected. The Red Beds surrounding the uplift contain large deposits of gypsum. Beds of bentonite and nodules of phosphate of lime occur in the Benton shales and inexhaustible supplies of limestone and building stones are obtainable from the mountains. Extensive beds of lignite coal underlie portions of the adjacent plains on both sides of the mountains, and these are mined profitably. Clays for brick making and other uses are available at many localities, but are in limited demand.[a]

COAL.

The "Laramie" formation is extensively developed in the wide synclinal basins on both sides of the Bighorn Mountains, and, as in most other regions, this formation contains large deposits of lignite. In portions of the area these deposits are thick and to some extent utilized commercially. The formation is several thousand feet thick, and on the eastern side of the mountains comprises three members, of which the upper one may be, in part at least, younger than Laramie in age. The basal member, the Piney formation, consists of 2,000 feet of sandstone and carbonaceous shale lying on the Parkman sandstone, which carries marine fossils and is supposed to represent the Fox Hills, for it overlies typical Pierre shale. The medial member is a thick mass of conglomerate of considerable extent, which contains materials from the mountains to the west. It has been designated the Kingsbury conglomerate. The coal measures occur next above and have a thickness of 4,000 feet or more. They have been designated the De Smet formation. In places, especially in the upper measures, the coals and coaly shales are widely burned and the resulting clinker, or clay baked and reddened by the heat, is a conspicuous and characteristic feature in the outcrop region. At some localities the coal is still burning. On the east side of the Bighorn Mountains the principal mines are near Sheridan and Buffalo, but the lignite could be worked at many other localities. The largest mines are at and near Dietz, on Big Goose Creek, 7 miles below Sheridan. The succession at this place is as follows:

Section at Dietz coal mine near Sheridan, Wyo.

	Feet.
Rusty slabby sandstone	2
Light-gray soft sandstone	18
Dark coaly shale with fragmentary leaf impressions	2
Blue clay	6

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[a] A detailed description of the Geology of the Bighorn Mountains, by N. H. Darton, is now in press as Professional Paper No. 51, U. S. Geol. Survey.

	Feet.
Shales, reddish, yellow, purple, and greenish	12
Dark-brown sandstone alternating with greenish-blue shale; concretions	25
Greenish-blue clay with small iron concretions	20
Coal, 1 foot on 1 foot of dark shale	2
Coal	3
Greenish-blue shale with large sandstone concretions	20
Brownish shale with leaf impressions on 8-inch sandstone bed	7
Coal, poor quality	6
Gray sandstone	4
Shale and coal	6
Greenish-blue shale with coaly layers	10
Sandstone	½
Coal, main bed at tunnel	7
Concealed	100
Coal at bottom of shaft	10
	260½

The 7-foot bed of coal has been extensively mined. The overlying layer of hard sandstone thins out about half a mile back in the mines and the two coal beds unite. The coal is of good quality for lignite, but slacks easily on exposure to the air. It is used on one section of the Burlington Railroad, about thirty locomotives having been specially modified for burning it. Besides supplying the railroad, the coal is shipped to local dealers in both the East and the West, especially at points in eastern Wyoming and Montana. It supplies some coal to the city of Sheridan, but the greater part of the coal used by the citizens of that place is furnished by other mines along Big Goose and Beaver creeks.

The Dietz tunnel has been worked back into the hills about 1½ miles. It rises with a slight incline for a short distance and then runs nearly on a level only a few feet below the surface of the ground. There are several side entries to the main tunnel which lead into rooms. The mine is kept well timbered, and as fast as the rooms are worked out the timbers are removed and the walls allowed to cave in. In 1902 a shaft was sunk 150 feet deep about half a mile northeast of the old tunnel. In this shaft the 7-foot seam mined in the old tunnel was penetrated at a depth of 40 feet, and a second bed 10 feet thick at a depth of 140 feet. This lower bed contains a coal that is harder and, as regarded by the miners, of better quality than that found in the old tunnel. It does not air slack easily and, according to tests made, is a good quality of steam coal. From the bottom of this shaft a main entry 10 feet deep runs over a quarter of a mile in a northeasterly direction, with side entries in process of construction. This shaft is equipped with a modern derrick, new engines for hoisting, and an elevator for loading coal on the railroad cars. The output of the Dietz Company is said to be 50 cars a day during the busy season, and the coal sells at the rate of $2 a ton.

On Owl Creek and the divide to the north the coal measures contain a coal deposit 18 feet thick, which is extensively mined. The coal outcrops across the divide toward Soldiers Creek, but appears to thin out rapidly in that direction, being only 6 feet thick in an abandoned mine on the north slope. To the south the coal outcrop encircles the hill lying between the mouths of Owl and Big Goose creeks, and is opened extensively at the Big Goose coal mine, on the east side of the hill. The bed here is 14 feet thick, but at Nelson Brothers' mine, 2½ miles farther southeast, on the east side of Beaver Valley, it thickens to 21 feet of pure coal. The strike of the beds is northwest and southeast in this region and the dip about 4°. The coal thins in every direction from the Nelson mine. The overlying beds exposed at intervals down Goose Creek are soft sandstones and shales with coaly layers.

The coal mines on Owl Creek, 2 miles northeast of Beckton, are owned and operated by Mr. R. S. Addleman. They were opened in 1897. The main tunnel is 800 feet long and runs from northeast to southwest, or nearly at right angles to the dip, which is about 4° NE. In 1902 there were 12 rooms 200 feet long, 18 feet wide, and 7 feet high. The coal deposit is 18 feet thick in its thickest portion, and 12 feet of this is good coal, but only 7 feet near the middle of the bed is worked. The top 3 feet is a mixture of coal and shale. The production is about 4,000 tons a year, which sells at $1 a ton at the mine. Half a mile east, in Big Goose Creek Valley, the same bed is opened at the Big Goose coal mine by Mr. H. Timm. Mining was begun in 1890, and in 1902 the main tunnel was 600 feet long, with two side entries 240 feet long, and had six rooms. The mine is operated only part of the year and has an output of 5 tons a day, valued at $1 a ton at the mine. It is used mainly in Sheridan and is entirely satisfactory for domestic use. Two and a half miles southeast, on the east side of Beaver Creek Valley, 2 miles above its mouth, is Nelson Brothers' coal mine, which has been in operation since 1899. The bed is the same one as in the other mines, but it is 21 feet thick without a parting. The owners are working only 9 feet at the bottom of the bed. There is a main entry 350 feet long, with numerous rooms 18 feet wide and 9 feet high. The mine is well timbered and has a tramway in the main entry. Eight men are employed in winter and two in summer. The average output is 15 tons a day in winter, which sells at $1.25 a ton at the mine.

At a coal prospect 3 miles northeast of Wolf post-office there is a layer of coal 1 foot thick. It is overlain by dark-reddish shales containing plant remains and lies on blue clay.

At one time coal was worked on North Dry Creek 2 miles south of Tongue River, but as the opening has caved in the beds could not be measured. In the bed of the creek near by 4 feet of coal are exposed, overlain by dark-brown leaf-bearing shales. The bottom of the coal bed is below the creek and the thickness could not be ascertained. Apparently it is the bed which was worked in the mine. The coal is of a good quality and easily mined.

Three miles east of Ranchester a draw on the south side of Tongue River exposes the following beds, having a very low dip:

Section 3 miles east of Ranchester, Wyo.

	Feet.
Rust-colored shale	2
Gray sandy shale	5
Coaly shale, plants	6
Red and gray shale	6
Sandstone, rust colored	2
Coal	1
Blue shale	1
Coal	1
Gray shale	10
Talus to river	9

These beds appear again north of the river, along the divide between Sixmile and Early creeks. On the summit of this ridge several thin layers of coal are exposed, varying from 1 inch to 4 inches thick, separated by 20 to 25 feet of bluish-green clay with ironstone concretions. On the north side of Early Creek, 3 miles northeast of Ranchester, the next higher beds are exposed, as follows:

Section 3 miles northeast of Ranchester, Wyo.

	Feet.
Clinker bed	10
Pale greenish-yellow clay	50
Red sandstone	4
Bluish-green clay	15
Gray sandstone	6
Light-yellow sandy clay	25
Bluish clay	15
Coaly shale, leaf impressions	8
Coal	4
Dark-gray shale	1
Coal	10
Bluish-green clay and shale	40
Coaly shale with thin coal streaks	20
Talus and red clinker-like rock	10
Light-brown clay with ironstone	20
Shale with plant fragments	2

	Feet.
Coal	⅓
Coaly shale	2½
Coal	1
Coaly shale	2
Coal	1
Blue-green clay	6
Coal	1
Dark clay and shale.	

The upper beds of this section cross Tongue River just east of the mouth of Early Creek, where the coal is mined in small amount. The thickness of the bed varies from 5 to 6½ feet. This coal is also mined to some extent for local use on the ridge to the northwest.

In the Clear Creek region the lignite-bearing beds of the De Smet formation succeed the Kingsbury conglomerate near Buffalo and extend eastward with a width of about 18 miles on Clear Creek. The dips are to the northeast at angles of from 10° to 20° a short distance west of Buffalo, but the amount decreases rapidly to the east. The beds comprise 5,000 feet or more of alternating shales and sandstones, the former mostly carbonaceous and the latter soft and massive. The stratigraphy is variable, and no regular succession of beds could be established. The coal occurs in local beds at various horizons, and, although most of the deposits appear to be of limited extent, a large amount of coal is available. There are four principal horizons lying near together a few hundred feet above the base of the formation. In the region northeast and east of Buffalo part of the coal has burned out near the the surface and the heat has baked the adjoining shales into red clinkers over wide areas. At some localities the coal is still burning, notably at an abandoned coal mine near the southeast corner of Lake De Smet.

The lowest member of the coal measures is a series of sandstones lying on the Kingsbury conglomerate and merging upward into coaly shale which extends north and south in the region north and west of Buffalo. On the east side of Rock Creek, in the northeast corner of T. 51, R. 83, it is 6 feet thick and contains three or four streaks of coal of poor quality. The principal coal deposits of the Buffalo region occur considerably higher in the formation, and one series outcrops along a zone extending from the southeast corner of Lake De Smet to the mouth of Rock Creek and thence east of Buffalo. Near Lake De Smet the old mines have caved in, but they appear to have worked about 4 or 5 feet of coal. It is overlain by a bed of clinkers. Near the mouth of Rock Creek, at the Bodan coal mine, a tunnel has been run in on a 12-foot coal bed of good quality, which is worked to a moderate extent every winter. The section at this place is as follows:

Section at Bodan coal mine, near Buffalo, Wyo.

	Feet.
Clinkers	6
Yellow sandy clay, with 6 feet of concretionary sandstone at base	30
Reddish-yellow clay	4
Dark shale with plants	2
Coal	12
Light-gray shale	2

The coal appears to be in a lens-shaped deposit and thins considerably to the north and south. A short distance north an 8-inch coal bed is seen underlying the clinker bed. A mile east of the Bodan mine and at a somewhat higher horizon is the old Foot mine, in which an 8-foot bed has been worked. It is overlain by 20 feet of light, sandy clay, 20 feet of dark shale with thin coaly streaks, and 15 feet of yellow sandy clay. This coal deposit is on fire and has been burning for several years. The following section at Monkers & Mather's mine, a mile east of Buffalo, shows the principal succession in that region. The lower 7-foot bed is probably the lowest bed of importance in the formation. The upper 7-foot bed is the one that reaches the surface near the mouth of Rock Creek, where, as above stated, it has been mined at several places. The next bed lies some distance above and is worked at the Mitchell mine, 2½ miles east of Buffalo, a short distance below the lower clinker bed. It is 6 to 8 feet thick.

Section at Monkers & Mather's coal mine east of Buffalo, Wyo.

	Feet.
Yellow sandy clay	6–8
Coaly shale	4
Grayish sandy clay	14
Coal	7
Shale	80
Coal on 1 foot of shale	3
Coal	2
Shale and slate	20
Coal on 1 foot of shale and coal	5
Coal on 2 inches of shale	7
Coal	3
Shale and slate	30
Coal	3
Shale and slate	17
Clay which burns to clinker in air	50
	253

In the vicinity of Buffalo the lignites are mined extensively for local use. There are four principal beds which outcrop in a zone of moderate width, passing north and south a short distance east of Buffalo. The beds generally vary from 5 to 12 feet in thickness and lie in a series about 200 feet thick, which dips very gently to the northeast. The principal mines are within 3 miles of Buffalo and lie to the east and north. Monkers & Mather's mine, the section of which is given above, is about 1 mile east of the town and is the principal producer. Its annual output averages about 2,000 tons, and the selling price is about $1.50 a ton at the mine. The workings are underground.

The highest coals in the Clear Creek region are found in isolated areas in the buttes and plateaus of the clinker region 10 miles northeast of Buffalo. The beds apparently are remnants of deposits which are burned out elsewhere. They are included in strata free from clinker and in part capped by gray sandstone and clay, which overlies the upper clinker bed in some other places in the region. A number of such occurrences were observed in and adjoining the northwest corner of T. 51, R. 80.

In their southern extension toward Crazywoman Creek the De Smet coal measures contain coal, but no large deposits appear. There is a uniform succession of sandstones and shales, with coaly layers at intervals. The stratigraphy is less marked than in the region to the north, and the only noticeable feature is the occurrence of clinker for a short distance in two lines of small buttes south and southwest of Long's ranch. Coal 6 feet thick is mined 2 miles southwest of Long's ranch, but it is not of very good quality. Toward Powder River thicker beds appear, and in the region about the head of the Belle Fourche there are extensive and thick beds, which extend southward to North Platte River to the mines at Glen Rock.

GOLD.

At intervals during the past decade attempts have been made to develop gold mines in the vicinity of Bald Mountain, but the results have not been encouraging. The basa gravels of the Deadwood formation, especially where mixed with disintegrated portions of the underlying granite, contain fine-grained free gold, but the values are low and the distribution irregular. The highest assays reported are $2 a ton, but the amount is usually so much less that the workings have not been profitable. At a point about 2 miles west of the abandoned Bald Mountain cabins a mill with jig machine was in operation in 1903, working the disintegrated sandstone and granite at the base of the Deadwood formation, but it is stated that only small portions of the material yielded paying results. Some of the small intrusive dikes or chimneys about Fortunatus Mill are reported to contain some gold, but the value is low and the extent of mineralization small.

Another locality at which the basal sandstone of the Deadwood formation has been found to contain gold is at the head of Kelly Creek, southwest of Buffalo. At this place a 3-stamp mill was built several years ago, which obtained a small product, but apparently without sufficient profit to give encouragement to continued operations.

The granite area of the Bighorn uplift has been extensively prospected for metallic minerals, but the results appear to be not encouraging. Small amounts of free gold occur in quartz veins connected with the diabase dikes in the granite, but the values are low. There are several prospects on the headwaters of East Fork of Big Goose Creek. The work was begun in 1898 and, although the results have appeared promising, no ore has been produced. A 350-foot tunnel is projected at one of the mines. The rock is a dark-gray granite containing some pyrite and a trace of copper. Assays of gold showing $4 a ton are reported. In one opening $12 of gold and $7 of silver a ton were found.

Considerable prospecting has been done in two large dikes southeast of Willitt Creek. The minerals are galena and pyrite, occurring in small streaks in quartz along diabase contacts. A few small prospects have been made in a quartz vein about a mile north of Tongue River Cabin. A mine on the ridge southwest of the mouth of South Fork of Tongue River, belonging to the Nickel and Copper Refining Company, has been worked at intervals since 1896, but is now abandoned. There is a shaft 180 feet deep, with buildings and extensive machinery. The shaft is sunk along the contact of a large dike of peridotite and a quartz vein, but apparently very little mineral was found. It is stated that platinum was one of the principal objects of the enterprise. Extensive prospecting was done at intervals along the dike, which has a length of about 3 miles. Traces of gold are found in gravels and sands along some of the streams flowing out of the mountains, but they have not been sufficiently promising to lead to any placer mining.

Rich gold prospects have been found in the crystalline rock area in the center of the Bridger uplift, 7 miles southwest of Deranch. Very promising prospects of gold have been found recently. The metal appears to be free and is partly in quartz veins and partly in association with copper ores. The extent of the deposit has not been ascertained, but numerous claims have been located, and doubtless these will soon be thoroughly explored.

Very little prospecting has been done in the high ridges about Cloud Peak, and possibly some of the great dikes which traverse the granite in that region may carry minerals of value, such as gold or even platinum, and the rare earths, some of which now have considerable economic importance. The dike rocks contain magnetite and titanic iron, but they are intimately intermixed with the other constituents, and consequently are of no value Assays of ordinary rock from the two largest dikes showed no traces of valuable metals.

COPPER.

Copper minerals, mainly malachite and red oxide, appear occasionally in the granite, and in the vicinity of Bull camp and Okie's store considerable prospecting has been done. Small amounts of moderately high grade ores are obtained, mainly from quartz veins in the vicinity of the diabase dikes. The principal prospects are east and southwest of Bull camp, one of the most extensive being near Beaver Creek, 3 miles east-southeast of that place. Here a shaft has been sunk 40 feet, but only a small amount of copper ore was obtained. Apparently the mineral is in minute veins widely scattered through the rock, and no bodies of economic importance appear.

On a branch of South Fork of Wolf Creek, southwest of Walker Prairie, several efforts have been made to develop a copper mine in a 15-foot quartz vein in the granite. A shaft has been sunk 56 feet and crosscuts made. The ore is mainly malachite, occurring in irregular veins in the quartz. Some galena also occurs and part of the vein carries gold amounting to from $3.50 to $4 a ton. The quartz vein at this locality extends about 3 miles southwest and the same distance east of the opening, passing under Deadwood sandstones at Walker Prairie. Near its northeast end, at Walker's mine, where it is about 25 feet wide, it has been prospected to some extent. A small amount of pyrites was obtained which carried small values of gold.

Copper minerals have been recently discovered in the granite area in the uplift of the Bridger Range, a few miles southwest of Deranch. One vein has been opened which shows a moderate-sized body of high-grade ore, consisting of oxides and sulphides. The openings are not yet sufficiently developed to exhibit fully the extent and value of the deposit. As stated in the preceding paragraph, considerable gold occurs with the copper minerals of this locality.

GYPSUM.

The gypsum in the Chugwater formation, on both sides of the mountain, is of excellent quality, in every way suited for the production of stucco and plaster of Paris. This product is prepared by calcining and powdering the mineral, which is a combination of sulphate of lime and water. The beds of gypsum occur generally near the base of the formation and a thickness of 10 to 15 feet is usually presented. Much of the material is of pure white color and is nearly pure. Owing to the lack of a local market and the fact that the value of plaster of Paris is too low to cover freight charges for long-shipments, this resource has no promise of development at present.

BENTONITE.

No bentonite has been observed in the immediate vicinity of the Bighorn Mountains, but as it occurs in adjoining areas and appears generally to be present in the Benton shale probably it will eventually be found. It occurs at two horizons, one below and the other above the hard shale or Mowry member. The mineral is a pale greenish-buff clay of compact texture and of such porous structure that it will absorb several times its bulk of water. On account of this absorbent quality it has a moderate market value for several uses.

LIMESTONE.

The limestones of the mountain slopes are in the main sufficiently pure for lime burning or for smelting flux, but there is very little demand for these products in the region. No analyses have been made to ascertain the chemical character of the rocks.

BUILDING STONES.

Many of the rocks in the mountain portion of the area are more or less well suited for building stone. Some of the granites are massive, have a fine appearance when polished, are relatively free from minerals which cause stains on weathering, and may at some time be valuable for shipment for building. Some of the limestones in the Madison formation are of very satisfactory texture and appearance and possibly could be worked for marble, especially the upper member. The Tensleep sandstone is usually massive, even textured, and of white or light-buff color, so that if nearer to markets it might be advantageously worked as a freestone. The red sandstones of the Chugwater formation are of a very pleasing color, but they are mostly too soft to be of value for building. Large supplies of rough stones for foundations and similar uses are obtainable from the Piney, De Smet, Parkman, and Cloverly sandstones and the hard ledges in the Sundance formation.

PHOSPHATE.

The spherical concretions occurring in the lower portion of the Benton formation consist mainly of phosphate of lime, and as they could be obtained in large numbers by means of suitable excavating machinery they may at some time be utilized as a source of phosphate.

PETROLEUM.

At various localities along the sides of the Bighorn and associated uplifts some of the sandstones and sandy shales contain petroleum. This material usually appears in springs or seeps in small valleys, and so far has been found only in limited amounts. The principal occurrences are on the sides of the uplift which rises east of South Fork of Powder River, in T. 38, R. 82, and T. 40, R. 79, the latter being in the valley of Salt Creek. Details regarding these occurrences are given in bulletins by the late Prof. W. C. Knight.[a]

Nine wells have been sunk on Salt Creek to depths of from 800 to 1,200 feet, some of which yield oil. The output of this field in 1905 averaged 35 barrels a day, which has to be hauled 50 miles to Casper at a cost of $2.80 a barrel. It sells at an average rate of $7 a barrel. The horizon appears to be sandstone at the base of the Pierre, or possibly the next sandstone stratum below, in the upper part of the Niobrara.

Oil springs of small volume occur in the vicinity of Bonanza, but a number of wells sunk in that field have failed to obtain a supply. The oil in the springs is from a horizon in the lower portion of the Benton.

ASPHALTUM.

A deposit of asphalt occurs in the Tensleep sandstone, on the west slope of the Bighorn Mountains, in secs. 28, 29, 32, and 33, T. 52, R. 89. The thickness is stated to be 6 feet, but the area has not been ascertained. The material consists largely of asphalt intimately mixed with coarse sand.

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[a] University of Wyoming Bulletins, Petroleum series, Nos. 1 and 4.

MINERAL RESOURCES OF THE BIGHORN BASIN.

By Cassius A. Fisher.

COAL.

General description.—Coal is the principal mineral resource in the sedimentary formations of the Bighorn Basin. It occurs mainly in the so-called Laramie formation, although on the west side of the district a coal, said to be of good quality, is found in the upper part of the Colorado formation, and on No Wood Creek, 12 miles southeast of Bonanza, a deposit of coal is mined from the Cloverly formation. The coal is found at various horizons throughout the "Laramie" formation, but the most persistent beds of workable thickness are in a basal member of this formation, or possibly in lower beds. Coal is of widespread distribution within the area occupied by the Laramie formation. The greatest development, however, is found in places where the larger streams expose the coal measures. Here the most favorable conditions exist for locating mines, and the increased settlement of the irrigated valleys along the streams affords a local market for the coal. A detailed description of the coal deposits in the various districts where the principal development has taken place has already been published,[a] but since this investigation was made several new mines have been opened and a brief account of these is here given.

Cody Coal Company's mine.—During the winter of 1904 the Cody Coal Company opened a mine on the north side of Shoshone River, about 3 miles east of Cody station. The coal occurs about 1,500 feet above the base of the Laramie formation, in beds dipping at an angle of 45° E. It is about 4½ feet thick and is apparently of good quality, although no analysis of the product is available. The opening of this bed is in the face of the bluffs about 30 feet above the railroad, so that the coal can be loaded for shipment at a small expense when the new sidetrack now being built is completed. The mine is well timbered and preparations are being made for extensive development. A section of the deposit is as follows:

Section at Cody Coal Company's mine, Cody, Wyo.

	Feet.
Dark sandy clay.	
Coal	4½
Coaly shale	2
Dark sandy clay	8
Gray massive sandstone	20

Arrangements are now being made by another company to mine coal at the same horizon on the south side of Shoshone River.

Silver Tip mine.—The deposit on Cottonwood Creek, on the north side of the divide between Clark Fork and Shoshone River, has been prospected at several places, but the principal opening, the Silver Tip mine, is in sec. 29, T. 58, R. 100. Here considerable coal has been taken out for the last three years, chiefly to supply the ranch trade of Clark Fork Valley. The total thickness of the bed is 5 feet, including two partings of impure coal and a thin layer of soft light-colored clay. The main entry is driven in about 125 feet from the outcrop and throughout this distance the character of the coal appears to be uniform. An analysis of this coal shows a moderate amount of fixed carbon and volatile matter, with relatively low percentages of water and ash. A section at the Silver Tip mine is here given:

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[a] Fisher, Cassius A., Coal of the Bighorn Basin: Bull. U. S. Geol. Survey No. 225, 1904, p. 345.

Section at Silver Tip mine, on Cottonwood Creek, Wyoming.

	Feet.
Gray compact sandy clay	4
Brown leaf-bearing shale	3
Coal	5
Gray sandstone	6
Impure coal with streaks of leaf-bearing shale	2
Dark-colored sandstone	5

Woodruff mine.—During the summer of 1904 an opening was made on a bed of coal in the upper part of the Laramie formation near the mouth of Meeteetse Creek, about 2 miles north of Meeteetse, Wyo. The seam is 4 feet thick with no partings. It is overlain by hard gray sandstone and underlain by a dark-colored compact clay. An entry 150 feet deep has been driven on the seam, with several large rooms on either side. The coal is hard and black, with a bright luster. It appears not to break up badly on exposure, and as a domestic coal is said to be very satisfactory. No analysis has been made of this coal. During the past two years the Woodruff mine has had a total output of 2,200 tons, which sells at $2.25 per ton. The coal finds a ready market at Meeteetse, Wyo.

Erskin mine.—Another mine, which is owned by Mr. Erskin, has recently been opened near Meeteetse, Wyo. It is located in sec. 13, T. 48, R. 101, about 2½ miles above Meeteetse, in the lowland of Gray Bull Valley. This mine is on the same seam which has been worked for many years on the north side of Gray Bull River, known as the Edward Blake mine. The coal beds have a dip of 6° E., and are somewhat thicker than on the opposite side of the valley. The output for last season during the period of development of the mine was about 700 tons.

No Wood coal.—An opening has been made in a coal bed which outcrops near the base of a prominent hill at the head of Bud Kimball Draw, 14 miles southwest of Tensleep, Wyo. Coal is not mined here regularly, but many of the settlers along No Wood Valley obtain their fuel supply from this place. The coal bed, which occurs in the lower part of the Laramie formation, has an aggregate thickness of about 6½ feet, consisting of four benches separated by partings of bony coal and brown leaf-bearing shale.

Section of No Wood coal near head of Bud Kimball Draw, Wyoming.

	Ft.	in.
Brown leaf-bearing shale.		
Very impure coal		10
Gray sandstone		4
Coal containing thin layers of bone	3	6
Brown leaf-bearing shale		10
Bony coal		3
Coal		9
Bony coal		4
Coal	1	6
Bony coal		6
Coal	1	0
	9	10

BENTONITE.

Bentonite deposits occur at various places throughout the Bighorn Basin. Those of most common occurrence are in the Colorado formation, being found at two or more geologic horizons. The thickest deposit observed is in a series of dark shaly beds about 100 feet below the Mowry beds. The bentonite at this horizon, in the northern part of the Bighorn Basin, has been described by the writer in a previous bulletin.[a] During the last field season deposits of this variety of clay were discovered in the lower part of the Laramie formation, also in the overlying Wasatch formation. Those in the Laramie formation are associated with thin deposits of coal and coaly shale in a series of sandy beds outcropping at the head of Bud Kimball Draw, 12 miles southeast of Tensleep, Wyo. A section of the deposit is here given:

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[a] Fisher, Cassius A. Bentonite deposits of Wyoming: Bull. U. S. Geol. Survey No. 225, 1904, p. 559.

Section of bentonite deposit at head of Bud Kimball Draw, Wyoming.

	Ft.	in.
Coal and brown leaf-bearing shale in alternate layers	2	
Dark-gray sandy clay	5	
Bentonite clay	3	
Dark leaf-bearing shale		6
Bentonite clay	3	
Light-gray clay	3	
Dark-gray sandy clay	3	
Gray sandstone	1	6
Impure coal		10
Gray sandstone.		

In the bad lands of the Wasatch formation, on the south side of Cottonwood Creek, about 10 miles southeast of Meeteetse, an impure bentonite occurs.

GYPSUM.

The gypsum deposits of the Bighorn Basin are mainly in the Chugwater formation. They occur also in the lower part of the Sundance formation and, at one locality, a deposit 8 feet thick was observed in the upper part of the Morrison formation. In the Chugwater red beds there is usually a gypsum layer 30 to 40 feet thick near the top of the formation and generally one of equal thickness at or near its base. Along the south side of the basin the gypsum at the base of the red beds is absent. Thinner beds of gypsum are found at various horizons in the Chugwater formation, but these appear to be of local deposition. In most places where the gypsum has been carefully examined it is apparently of good quality, though no analyses have been made to determine its exact chemical nature. It is white, compact, and massive, and generally occurs in beds that are free from partings. The following section, taken on Trail Creek northwest of Cody, will show the position of the gypsum in the upper part of the Chugwater red beds:

Section of a portion of the Sundance and underlying Chugwater formations on Trail Creek, Wyoming.

	Feet.
Green shale containing thin limestone layers (Sundance)	3½
Red sandy shale containing thin layers of gypsum (Chugwater)	12
White massive gypsum	30
Red sandstones ("Red Beds").	

About 10 miles south of Cody a deposit of gypsum was observed in the upper part of the Morrison formation. The following section shows its relative position:

Section of a portion of the Morrison and overlying Cloverly formations south of Cody, Wyo.

	Feet.
Brown, coarse-grained, cross-bedded sandstone (Cloverly)	60
Reddish sandy shale with thin gypsum layers	25
White massive gypsum	8
Reddish sandy shale with thin gypsum layers	15

Though there are extensive deposits of gypsum throughout this area, no attempt has been made to utilize the product, except in a very small way. At a stucco mill about 10 miles northeast of Windsor post-office, Wyo., across the Montana line, plaster is manufactured from a gypsum deposit near the base of the Chugwater red beds. The beds mined at this place are about 15 feet thick and the product is of good quality. The material is ground and placed in ovens where it is calcined at a red heat in order to drive off the chemically combined water. A retarder is then added to prevent it from hardening too quickly when water is applied. After this it is mixed with hair and placed in barrels ready for shipment. The entire process of converting the gypsum into stucco is relatively simple and inexpensive. The finished product of this mill is sold at Bridger at $12 a ton, but the output is not large.

An analysis of gypsum from the Chugwater formation near Bowler, Mont., was made by Mr. W. O. Dickinson, assistant in chemistry at the State University of Montana, as follows:

Analysis of gypsum from Chugwater formation near Bowler, Mont.

CaO	33.02
SO_3	45.93
H_2O	21.04
	100.00

OIL AND GAS.

Several attempts have been made to obtain oil from the Cretaceous shales throughout the Bighorn Basin, but generally without success. About three-fourths of a mile southwest of Bonanza, near the axis and at the north end of an anticline in the Colorado formation, there are several oil seeps which furnish a small amount of oil. The oil is from a thin-bedded sandstone under the Mowry beds of the Colorado formation. This surface indication has caused many persons to believe that oil in paying quantities might be obtained by drilling, and consequently several deep borings have been made in this region. None of these have been successful and at present all exploration has ceased. The oil from this locality has been analyzed by Prof. E. E. Slosson, of the University of Wyoming, and is reported to be of good quality, but the amount is too small to warrant development.

A deep boring for oil was made at the mouth of Cottonwood Creek, on Shoshone River, near Cody, Wyo., but no oil was obtained. The well is located on the west slope of a small anticline in Colorado formation.

Byron gas well.—Plans are now being made to sink a deep well on the west side of a broad anticline along the axis of which a small area of Pierre shale is exposed. Shoshone River crosses the south end of the anticline and has cut for some distance into the shale. In the low valley of this stream, near the center of the anticline, there are places where gas escapes in considerable quantity from the alluvial sands. It is probably derived from the underlying shales of the Pierre formation. The gas burns readily, but its quality was not ascertained. The boring which is now proposed will doubtless demonstrate whether or not gas is present in sufficient amount to warrant development.

About 3 miles east of Basin, Wyo., a small well is being dug in the Pierre shale for the purpose of finding gas. The present depth of the well is about 60 feet and an appreciable amount of gas has already been obtained. A small company has been organized and the work will be continued.

MINERAL WATER.

Cody Hot Springs.—About 3 miles west of Cody, Wyo., in the bed of Shoshone River, there are a number of hot mineral springs. The water from these springs contains a large amount of hydrogen sulphide and probably some sulphuric acid. The temperature of the water is 98°. There is a sanitarium near the springs and the water is used for medicinal purposes.

Thermopolis Hot Springs.—At Thermopolis, on Bighorn River, in the southeastern part of the Bighorn Basin, there is a hot mineral spring the flow of which has been variously estimated at from 2,000 to 3,000 gallons a minute. Calcium carbonate is the principal ingredient of the water, while magnesium, sodium, and calcium sulphates are present in smaller amounts. An analysis of this water, made by Prof. E. E. Slosson, of the University of Wyoming, is here given:

Analysis of water of Thermopolis Hot Springs, Wyoming.

	Grains per gallon.
SiO_2	4.986
Fe_2O_3 and Al_2O_3	.227
KCl	10.249
Na_2SO_4	15.110
Mg_2SO_4	19.443
$CaSO_4$	13.156
$CaCO_3$	40.454
NaCl	26.195
	129.811

There are two sanitariums and a large plunge located near the spring and the place is rapidly becoming a popular health resort for the people of northwestern Wyoming.

SULPHUR.

Sulphur occurs in local deposits on the south side of Shoshone River, at the lower end of Shoshone Canyon, and along the west side of Sulphur Creek for about 2 miles above its mouth. It was deposited by heated waters and gas from the numerous geysers that once existed in this region. A large amount of prospecting has been done, with a view of developing this resource. The material appears to be of excellent quality and, if it occurs in sufficiently large quantities, might be profitably worked. Sulphur also occurs in the hot-spring deposits at Thermopolis.

THE NORTH DAKOTA-MONTANA LIGNITE AREA.

By A. G. LEONARD.

LOCATION.

The North Dakota-Montana lignite area includes most of the western half of North Dakota, eastern Montana, and the adjoining parts of South Dakota and Wyoming; it also extends north into Canada. Lignite is known to occur as far west as Bighorn River and the mouth of Milk River in Montana and the Bighorn Mountains in Wyoming, or about 150 miles west of the North Dakota line. In South Dakota the lignite is confined to the northwest corner of the State. Farther west the lignite field extends south into Wyoming, where it includes portions of Sheridan, Johnson, Crook, and Weston counties. The area has an extent of about 350 miles east and west and at its widest part nearly the same extent north and south, containing approximately 100,000 square miles. This is over twice the area of New York State and is about equal to that of Colorado. North Dakota and Montana each includes about 40,000 square miles of the total area.

TOPOGRAPHY.

The topography of by far the greater portion of this extensive region is that of a gently rolling or rough plain which has an elevation of from 2,000 to nearly 3,000 feet above sea level. Rising above the general level of this plain and forming conspicuous features of the landscape are numerous flat-topped buttes and hills. Slim Buttes and Cave Hills in South Dakota and Sentinel Butte, Bullion Butte, and the Killdeer Mountains in North Dakota are notable examples. They rise abruptly from 400 to 600 feet above the plain. The buttes are especially characteristic of the eastern part of the region, in North and South Dakota.

On the northern and eastern borders of the lignite area the surface has been modified to a considerable extent by the continental ice sheet, which left behind a mantle of bowlder clay, sand, and gravel that forms a gently rolling plain. This drift plain is found east and north of Missouri River and extends 50 miles and more south and west of that stream.

A striking contrast to the flat, wide prairies is furnished by the extremely rough badland areas bordering the streams and frequently extending back from them many miles. The bad lands are perhaps best developed along Little Missouri and Yellowstone rivers, though they are by no means confined to the vicinity of these streams.

The lignite area is traversed by several rivers of importance, whose broad, deep valleys form conspicuous topographic features, besides affording favorable routes for railroads. Those of the Missouri and Yellowstone are the most extensive, being from 200 to 300 feet deep and from 1 mile to several miles wide; of less importance are the valleys of Little Missouri, Tongue, and Powder rivers.

STRATIGRAPHY.

Pierre shale.—All the rocks exposed in the lignite area belong to the Cretaceous system. Those immediately underlying the coal-bearing beds belong to the Pierre shale, which also borders the "Laramie" [a] or coal-bearing formation on the east and south. The bluish-gray, jointed shales of this formation are brought to the surface by an anticline along Yellowstone River 12 miles above Glendive, Mont., at the mouth of Cedar Creek. The Laramie beds on the south side of the creek have a dip of 25° SW., while on the north side of the creek valley occurs the Pierre shale with many characteristic fossils. There are here 200 feet of dark shale overlain by 150 to 200 feet of light-buff shale. Scattered through these beds are abundant siliceous and ferruginous nodules of lime carbonate, often rich in fossils. The fossil-bearing nodules are most numerous toward the top of the dark shale, in a horizon 250 to 300 feet above the river. The Pierre strata are seen outcropping in the bluffs of the Yellowstone for a distance of at least 5 or 6 miles. Shale similar in appearance and with many of the same Pierre fossils occupies an area of considerable size in western Bowman County, N. Dak., and extends across the line into Montana. This belt stretches many miles north and south on either side of the boundary line and has a width of from 3 to 10 miles or more. It is not unlikely that the Pierre outcrops at other points within the lignite area, but the above were the only localities found during the past season.

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[a] In conformity with common usage in the North Dakota field, the term Laramie is here used for the lignite-bearing beds, although it is recognized that the name Fort Union may be more appropriate.

Fox Hills sandstone.—At some localities the Fox Hills sandstone lies between the Pierre and Laramie formations, but generally it is absent in this field. Outcrops of this formation are extremely rare, the only one known being in Morton County, N. Dak., on Cannon Ball River. About 8 miles above the confluence of this river with the Missouri a brown, ferruginous, friable sandstone occurs containing *Tancredia americana* M. & H. and *Callista* sp., possibly *Callista nebrascensis* M. & H. These fossils were identified by T. W. Stanton, and doubtless are of Fox Hills age.

Laramie formation.—The lignite occurs in the Laramie beds, which show remarkable uniformity in character over the entire region. They are composed of semiconsolidated sands and clays, the sand being in some places cemented into a more of less firm sandstone. In certain localities sandy strata predominate; in others clay and sandy clay constitute the bulk of the formation. The character of the Laramie formation is shown by the following sections:

Section in the bluffs of the Little Missouri at Medora, N. Dak.[a]

	Ft.	in.
40. Shaly sandstone, gray, weathering to yellow, finer grained than No. 39; contains cherty layer	15	
39. Sandstone, dark gray, rather soft, coarse grained, massive; forms vertical escarpment near top of bluff	45	
38. Lignite seam and coaly shale		1-4
37. Clay shale, gray and yellow	9	
36. Lignite seam		3-4
35. Clay shale		6
34. Gray, fine-grained, shaly sandstone	6	
33. Yellow clay shale	1	6
32. Lignite seam		6
31. Gray clay shale	1	
30. Gray sandy shale	6	
29. Gray clay shale	1	6
28. Chocolate-brown clay shale, with thin lignite seam	1	
27. Gray clay shale	4	
26. Soft shaly sandstone, gray and bluff, laminated, fine grained; in places forms hard sandstone ledge projecting beyond the softer shales above and below	15	
25. Gray and yellow clay shales, with some sandy layers	5	
24 Chocolate-brown clay shale, with plant impressions		4
23. Lignite seam	1	6
22. Clay shale, gray and yellow, with some sandy layers and a thin streak of lignite	30	
21 Sandy shale, passing above into a compact, hard, fine-grained gray sandstone; this rock forms a projecting ledge	3-4	
20. Gray and yellow clay shale	5	6
19. Fine-grained sandstone, forming projecting ledge	2	

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[a] Third Bienn. Rept. Geol. Survey North Dakota, pp. 161-162.

	Ft.	in.
18. Gray and yellow clay shale	4	6
17. Gray, fine-grained, sandy shale	6	
16. Lignite streak and chocolate-brown shale		½
15. Gray sandy shale and soft sandstones; in places the sandstone is cemented into hard rock, forming projecting ledge	7	
14. Gray clay shale	1	
13. Chocolate-brown shale		8
12. Lignite	1	
11. Gray and yellow clay shale	25	
10. Chocolate-brown shale	2	
9. Lignite	4	
8. Chocolate-colored clay shale with abundant plant remains, mostly stem impressions	1	
7. Gray clay shale	3	
6. Sandy shale and fine-grained sandstone	16	
5. Clay shale	4	
4. Sandy clay shale	6	
3. Gray clay shale	1	
2. Lignite	9	
1. Gray clay shale, not well exposed, to river	40	
	286	

The beds constituting the top of the Laramie are exposed in Sentinel Butte, where the section given below is shown:

Section at Sentinel Butte, North Dakota.[a]

	Ft.	in.
29. Alternating layers of highly calcareous gray clay and very fine-grained, compact, brittle, gray limestone, finely laminated, and more or less siliceous. Some of the sandstone beds weather into thin laminæ, one-sixteenth of an inch thick and less	7	
28. Very calcareous gray clay, weathering to a greenish color	18	
27. Gray hard sandstone	40-50	
26. Gray and yellow sandy clay	25	
25. Brown clay and thin seam of lignite	1	6
24. Gray and yellow sandy clays	48	
23. Lignite		6
22. Soft, fine-grained argillaceous sandstone	12	
21. Brown and gray clay shale containing many selenite crystals	4	
20. Soft, fine-grained sandstone	1	
19. Lignite	1-1	6
18. Chocolate-brown clay shale, with carbonized wood	1	
17. Bluish-gray clay	10	
16. Gray sand, cemented in places into soft sandstone	12	
15. Not well exposed, but probably clay shale	50	
14. Lignite		2
13. Gray sandy clay	32	
12. Gray clay shale with no sand	2	
11. Lignite	6	
10. Sandy clay shale, colored brown above	5	
9. Fine gray sand	4	
8. Gray sandy clay shale, containing nodules, similar to No. 6	14	
7. Finely laminated sand	4	
6. Gray sandy clay shale with ferruginous bands	8	
5. Chocolate-brown sandy clay shale	1	
4. Gray clay shale	5	
3. Sandy gray clay, containing abundant siliceous iron nodules, arranged mostly in bands at certain horizon. These hard nodules project from the surface of the softer clay and also cap small clay columns.	20	
2. Unexposed; includes some sand	20	
1. Lignite, outcropping in bottom of ravine near the east end of the butte, exposed	20	
	378	8

Nos. 28 and 29 of the above section are probably Tertiary.

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[a] Third Bienn. Rept. Geol. Survey North Dakota, pp. 165-166.

The number of lignite seams which may be present in a single section is well exhibited in the bluffs of Little Missouri River 5 miles above the mouth of Cherry Creek, in northwestern Dunn County, N. Dak.

Section on Little Missouri River 5 miles above Cherry Creek.

	Ft.	in.
53. Clay, to top of bluff	35	
52. Lignite	1	3
51. Clay, gray and buff	55	
50. Brown clay shale	4	
49. Lignite	1	
48. Clay shale	40	
47. Lignite, 302 feet above river	7–8	
46. Clay shale	18	
45. Lignite with some clay		10
44. Clay shale	24	
43. Lignite	2	6
42. Brown and gray clay shale	4	
41. Sandy clay	6	6
40. Clay shale	3	
39. Lignite, 240 feet above river	4	
38. Gray clay shale	17	
37. Lignite		10
36. Gray clay	2	
35. Gray sand	11	
34. Sandstone ledge	2	
33. Gray sand	2	
32. Gray and yellow clay, flaky	15	
31. Lignite		4
30. Gray and yellow clay; breaks into thin flakes	4	6
29. Lignite		7
28. Gray clay; crumbles into thin flakes	4	
27. Yellow sandy clay	5	
26. Gray clay	2	
25. Gray sandy clay	3	
24. Gray and yellow clay in alternating bands	4	
23. Brown clay shale		6–10
22. Gray clay	5	
21. Sandy clay	7	
20. Gray clay shale with calcareous, ferruginous concretions	6	
19. Sand, showing cross lamination	18	
18. Lignite, 130 feet above river	2	
17. Gray clay shale; crumbles into thin flakes	5	
16. Gray sand	15	
15. Lignite		8–10
14. Gray sandy clay	30	
13. Gray and yellow sand, with iron nodules	10	
12. Yellow and gray clay shale, with iron nodules	10	
11. Lignite with seams of brown clay	1	6
10. Gray clay shale; breaks into flakes	8	
9. Lignite		2–3
8. Gray clay shale		7
7. Gray sand	2	
6. Yellow and gray clay shale; breaks into flakes	2	
5. Brown clay shale		4
4. Lignite		9
3. Gray clay shale	30	
2. Lignite		9
1. Clay shale, to river level	15	
	451	

In southeastern Custer County, Mont., the Laramie formation is made up very largely of an indurated sandstone occurring in massive ledges and with a thickness of from 150 to 300 feet. This rock is finely exposed along Big Box Elder Creek, where it forms vertical cliffs bordering the valley, and in the Long Pine Hills in the vicinity of Camp Crook, S. Dak. At the Mill Iron ranch, on Big Box Elder Creek, about 10 miles above the boundary line, the sandstone is well shown in the following section:

Section at Mill Iron ranch, on Big Box Elder Creek, Montana.

	Ft.	in.
8. Sandstone in massive ledges alternating with softer, thin-bedded layers; shows cross bedding in places	160	
7. Gray clay	6	
6. Lignite	1	2
5. Clay		10
4. Lignite		10
3. Clay	5	
2. Lignite	1	6
1. Unexposed to creek	45	
	220	4

This thick sandstone was found to extend southward for 30 miles to the Long Pine Hills. In these hills the arenaceous strata have a thickness of from 250 to 275 feet, the rock being gray and yellow and weathering unevenly into a variety of fantastic forms. Many of the higher buttes of North and South Dakota are capped with sandstone beds belonging to the Laramie and having a thickness of 50 to 75 feet and over.

The foregoing sections may be taken as representative of the Laramie formation. They show that it is composed of alternating beds of clay and sand, together with seams of lignite. In places the sand layers are cemented into a firm, hard sandstone, but commonly they form incoherent beds, readily crumbling in the hand. These arenaceous strata, however, resist the action of weathering agencies better than the clays, and their outcropping edges form vertical ledges, often projecting beyond the clays. The presence of the sandy beds can thus commonly be detected at a distance by the character of the slope.

Probably two-thirds of the thickness of the Laramie is made up of clays, though this varies in different places. These clay shales range in composition from very pure clay through beds containing an increasing percentage of sand to those with only a small proportion of clay. The argillaceous strata thus graduate into the sandy layers through every intermediate mixture of clay and sand, and we have sandy clays and clayey sandstones. Many of the so-called clays are, strictly speaking, impure sandstones. In some cases the change from clay shale to sand is abrupt; in others it is gradual, the clay becoming more sandy near the line of contact.

One of the most marked features of the Laramie is this rapid alternation of sand and clay strata and the frequent occurrence of beds of lignite. The colors of the clay are white, gray, yellow, brown, and red, the grays and yellows predominating. The brown layers are rich in plant remains, and it is to the presence of this carbonaceous matter that they owe their color. These varied colors give the formation its banded appearance and add greatly to the beauty and variety of the landscape.

Crystallized gypsum or selenite is common in the clay. It is particularly liable to occur in the brown layers immediately beneath the lignite seams. The crystals are often very much elongated, some being found 8 and 10 inches in length, and are seldom perfect, the faces being more or less etched.

Of still more frequent occurrence are ferruginous nodules and concretions, composed either of iron pyrites or of limonite. They usually contain more or less siliceous or argillaceous material, and after exposure to the weather stain the clay about them yellow. Many of the clay slopes are thickly dotted with these nodules and concretions of all shapes and sizes up to several feet in diameter. Thin, impure limonite or clay ironstone bands, yellow in color, are not uncommon in the clays.

Another feature of the Laramie clays and sands which can not fail to attract the notice of even the casual observer is the great quantity of burnt and fused clay which is seldom absent wherever there are extensive outcrops of the beds. This red clay has been produced by the heat generated by the burning of the seams of lignite, which has doubtless been going on ever since the formation of the seams. Bands of this material may be traced for many miles along the bluffs of the stream valleys and in the buttes representing the horizons of burned-out lignite seams, portions of which are often found intact at some points.

The Laramie beds have a thickness of at least 1,800 feet in the western part of North Dakota. The Medora well, 941 feet deep, did not pass through them, and Sentinel Butte rises 860 feet above the curb of the well. This is perhaps the maximum thickness of the formation in North Dakota and it grows thinner toward the east until it is only a few hundred feet and less beyond Missouri River.

Tertiary.—The youngest strata occurring in the lignite area are certain beds which are referred to the Tertiary. These form the upper strata of the Slim Buttes and East and West Short Pine Hills of South Dakota, the Long Pine Hills of Montana, and the low mound on top of Sentinel Butte, North Dakota. The beds consist mostly of fine-grained, white, soft sandstone, with some calcareous clay and limestone. Their thickness in the Slim Buttes is 200 to 240 feet, and in the East Short Pine Hills they attain nearly 300 feet. The white sandstone forms conspicuous cliffs toward the top of the buttes, which can be seen from a great distance.

LIGNITE.

Interstratified with the sands and clays of the Laramie are seams of lignite. These are not confined to any particular horizon or horizons, but are distributed quite uniformly from top to bottom of the formation. In the Slim Buttes of South Dakota a 5-foot seam occurs 95 feet from the top of the Laramie. The 21½-foot seam in Sentinel Butte lies 340 feet below the top, and there is an 18-inch seam 142 feet below the same horizon. On the other hand, the records of deep wells at Medora and Dickinson show that the lignite is found toward the base of the formation. The seams thus have a vertical range of 1,500 feet or more.

The number of seams varies considerably in different parts of the field. At some points but two or three seams appear, while in other localities there are ten or fifteen in a vertical distance of from 250 to 500 feet, though many of them are only a few inches in thickness. Rarely are several hundred feet of Laramie strata exposed without one or more lignite beds. In the section already given (p. 319) appearing in the bluffs of the Little Missouri near the mouth of Cherry Creek, there are no less than fifteen seams within a vertical range of 480 feet, having an aggregate thickness of 25 feet. In the Third Creek district, 8 miles north of Glendive, Mont., four lignite seams, 7, 8, 10, and 14 feet thick, respectively, occur in a vertical distance of 200 feet, their aggregate thickness being 39 feet. In the 180 feet of Laramie clays exposed in the bluffs on the south side of Missouri River 3 miles below Williston the thickest of the six seams present is only 2 feet and the aggregate thickness is less than 3 feet. The Medora well passed through 941 feet of Laramie strata without reaching their base and encountered seventeen seams with a total thickness of more than 60 feet. The Dickinson well, with a depth of about 1,075 feet, penetrated sixteen seams, their aggregate thickness being about 55 feet.[a]

The lignite seams vary in thickness from an inch and less to 33 feet. Seams 6, 8, or 10 feet thick are common; seams from 10 to 20 feet thick are not rare, but those over 20 feet thick seldom occur.

The seams are usually not continuous over very large areas. A particular seam will pinch out within a mile or two and perhaps be replaced by another at about the same or a different horizon. Two seams may overlap each other and, while both appear at one point, at another half a mile or so distant but one of them is present. It is frequently not possible to correlate seams on the opposite sides of the same valley and only 1 or 2 miles apart. On the other hand, some seams can be traced 3 or 4 miles in the river bluffs and less commonly twice that distance, but sooner or later they thin out and disappear. This lack of persistence makes it unsafe to correlate lignite beds whose outcrops are separated by more than a few miles.

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[a] Darton, N. H., Preliminary report on artesian waters of a portion of the Dakotas: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 663.

The lignite differs considerably in appearance and physical properties in different parts of the region, though it is remarkably uniform over extensive areas. In North and South Dakota it is usually brown in color and more or less woody in character, exhibiting clearly the grain of the wood and having the toughness of the same material. It is difficult to break this lignite except along the grain, but it splits or breaks readily in that direction. Often portions of flattened tree trunks or branches are found in the seam, resembling much the original wood except for their brown color. The same seam is frequently more woody in some portions than others, being made up of alternating bands of tough brown lignite and black, lustrous, more brittle material. The lignite changes in character toward the west and in Montana much of it is black and lustrous, with little of the woody texture and appearance characterizing it in North Dakota, while it is almost as brittle as bituminous coal. This is much easier to mine than the tough brown variety, since it breaks up readily with the pick or in blasting. The lignite in the 9-foot seam at Medora and the 21½-foot seam in Sentinel Butte is woody and brown from top to bottom; that in the 12-foot seam on Beaver Creek, near Wibaux, Mont., is mostly black and lustrous, with only a few brown layers; while the lignite in the vicinity of Glendive is wholly of the black, brittle variety.

When exposed to the air for a short time the lignite loses much of its moisture and crumbles into small fragments. For this reason it is very desirable that the coal be used as promptly as possible after it is mined, before it has time to disintegrate, or "slack."

The chemical composition of the lignite is shown in the following analyses. The first was made at the United States Geological Survey coal-testing plant at the Louisiana Purchase Exposition and reported in Bulletin No. 261. The other analyses are taken from the Second Biennial Report of the North Dakota Geological Survey.

Analyses of lignite from North and South Dakota.

	1.	2.	3.	4.
Moisture	39.56	43.78	40.25	28.09
Volatile matter	27.78	26.07	25.21	37.78
Fixed carbon	26.30	26.33	27.17	27.86
Ash	6.36	3.82	7.37	6.27
Sulphur	.93	.61	.50	.72

1. From mine of Cedar Coulee Coal Company, near Williston, N. Dak.
2. From 33-foot seam on Sand Creek, at Russell ranch, Billings County, N. Dak.
3. From 9-foot seam on Riley ranch, at the base of the Cave Hills, Butte County, S. Dak.
4. From 7-foot seam near Cartwright, Allred County, N. Dak.

In the following analyses the fixed carbon, volatile matter, and ash are computed on a dry basis:

Analyses of lignite from various mines in North Dakota.

Mine and location.	Fixed carbon.	Volatile matter.	Ash.	Moisture.
Mouse River Lignite Co., Burlington:				
4 feet from bottom	51.28	35.83	11.89	32.00
Top	46.42	32.60	20.98	30.00
16 inches above clay seam	47.36	42.14	10.50	29.40
Lower 20 inches	52.96	38.93	8.11	34.70
Electric mine, Kenmare:				
4 feet from floor	57.95	34.41	7.64	32.90
3 feet from floor	59.19	36.56	4.25	35.00
Bottom	56.58	34.44	6.98	34.8
Top	56.87	36.58	6.55	34.8
Diamond mine, Kenmare:				
Top	52.98	37.24	9.78	33.00
Center	56.82	33.77	9.41	33.00
Lower 18 inches	56.97	36.28	6.75	33.60
Dakota Lignite and Brick Co., near Burlington	55.61	40.08	4.30	23.40
New Era mine, near Minot	57.66	38.22	4.12	33.6
Smith-Kenmare Dry Coal Co.:				
Next to clay	55.55	36.79	7.67	33.2
Next to roof	52.30	39.90	7.80	32.00
1 foot below roof	55.25	33.50	11.25	32.60
Wadeson mine, Sims	50.47	39.21	10.32	30.29
Lehigh mine	51.62	43.18	5.21	34.3
Satterlund mine, near Washburn	55.89	37.50	6.61	30.91
Washburn mine, Wilton	54.93	38.75	6.32	31.82
Dickinson Brick Co	46.89	38.23	14.88	27.82
Heart River, near Dickinson	60.49	38.31	1.20	14.25
Consolidated Coal Co., New Salem	53.86	41.66	4.48	27.48

Tests of the lignite as a gas producer were carried on at the coal-testing plant at the Louisiana Purchase Exposition, and the results, which are embodied in Bulletin No. 261, show that the lignite is an exceptionally good gas-producer fuel. It would be ideal for the purpose except for the tendency to clinker.

Lignite in the Little Missouri River basin south of Medora, N. Dak.—The coal seams described under this heading outcrop in the valley of the Little Missouri and its tributaries, the area within which they occur extending 50 miles south of the Northern Pacific Railway. Lignite is abundant in this district, and the seams are both numerous and thick. Four or five workable beds are occasionally present in a vertical distance of 200 feet. Seams 6, 8, or 10 feet thick are of common occurrence, while several beds with a much greater thickness are found. The seams will be described in the order of their appearance from Medora up the river.

Near the base of the bluffs at Medora, at an elevation of 40 feet above the river, is a 9-foot seam which has been mined for a number of years. Thirty-one feet above this is an upper seam 4 feet thick. Five miles south of Medora, at the Custer Trail ranch, two 5-foot seams outcrop in the bluffs on the east side of the valley, one 75 and the other 130 feet above the river. Four and a half miles farther up the river a seam of lignite 15 feet thick outcrops in a cut bank just above water level. It contains several clay bands, including one 12 inches thick near the top of the seam. Lignite is mined here by the ranchmen of the vicinity, but the mine is difficult of access except in winter, when teams may be driven to it on the ice. Still farther up the river, on the Hanley ranch, about 3 miles below the mouth of Third Creek, 6 to 8 feet of lignite are exposed in the bluff along the Little Missouri.

On Third Creek lignite appears at many points. About 4 miles above its mouth, near the McLellan ranch, in sec. 4, T. 136 N., R. 101 W., the following section is exposed:

Section of lignite at McLellan ranch, on Third Creek.

	Ft.	in.
Clay	20–100	
Lignite	8	6
Clay	7– 8	
Lignite	9	2
Clay	2	9
Lignite	3	6
Unexposed to creek	7	6

These three seams outcrop continuously for over 200 yards and have a slight dip to the east. The lowest one contains thin clay layers, but the lignite of the upper beds is of excellent quality. Seven or eight miles south of this point, on a small tributary of Sand Creek, three seams of lignite occur at approximately the same horizon as those found on Third Creek and are doubtless to be correlated with them. The following section is shown:

Section of lignite near Sand Creek.

	Ft.	in.
Clay	8–9	
Lignite	8	
Clay	2	6
Lignite	8	9
Clay	4	
Lignite	6	
Clay	4	3
Sandstone	1	

The seams exposed in the above section have burned out extensively, and the red, burnt clay thus formed covers large areas in several townships. At about the same horizon as this burnt clay is the thick lignite seam exposed on Sand Creek at the Russell ranch in sec. 31, T. 135 N., R. 101 W. The section shown here is as follows:

Section of lignite at Russell ranch on Sand Creek.

	Ft.	in.
Clay	6–12	
Lignite	4	3
Clay	2	10
Lignite	33	
Clay, to creek bed	4	

The lignite lies quite near the surface, and over large areas it has been eroded by Sand Creek and its tributaries, or burned, as stated above. This same seam appears along the creek from one-fourth to one-half mile to the south, and probably underlies a wide area on both sides of Sand Creek Valley. The 33-foot seam shown in the above section is, so far as known, the thickest which occurs in the entire lignite region of North Dakota and Montana. It has been reported to have a thickness of 40 feet, but careful measurement showed it to be 33 feet, though if the upper seam and the clay bed between are included the total would be 40 feet. There is reason to believe that the seams outcropping on Sand Creek are to be correlated both with those exposed 7 or 8 miles north and west on the tributary of the same creek and with those still farther north on Third Creek. If this correlation is correct, these thick seams cover an area at least 15 miles long from north to south and with a width probably as great. Other beds of lignite occur at several points farther south on Sand Creek.

In that part of the valley of the Little Missouri which has an east-west course for many miles a 13-foot seam is exposed not far from the mouth of Deep Creek. Many lignite seams occur above this point in the vicinity of Yule. In the river bluffs about 2 miles below the post-office, on the east side of the valley, three seams are present, as shown in the following generalized section:

Generalized section 2 miles below Yule.

	Feet.
Clay and sand	4- 50
Lignite	8- 10
Clay and soft sandstone	35
Lignite	7- 8
Clay and sand	100
Sandstone ledge	1
Lignite	8
Clay, to river level	30

The lower seam outcrops at several points in the cut banks on both sides of the river for a distance of 2 or 3 miles. The two upper seams are exposed in the badlands bordering the valley on the east. Along the river above Yule a 10-foot seam of lignite occurs near water level and can be traced for several miles. It has been mined and used by those living in the vicinity, but can not be reached except in winter, when the river is frozen. Above this bed there are two others 2½ and 3 feet thick, respectively. A second 10-foot seam is exposed near the top of the bluff 1 mile south of Yule, on the west side of the valley. Two and one-half miles southwest of the place just described another bed of lignite 10 feet thick occurs at the mouth of Deer Creek, at an elevation of 55 feet above the river. This seam outcrops at various points for a mile or more along the valley of the creek. In a ravine entering Little Missouri Valley 2 miles above the mouth of Deer Creek, in sec. 16, T. 135 N., R. 105 W., six seams are exposed within a vertical distance of 165 feet, as follows:

Lignite beds 2 miles above mouth of Deer Creek.

	Feet.
160 feet above the river	8-9
110 feet above the river	3
85 feet above the river	1-½
80 feet above the river	4
58 feet above the river	10
44 feet above the river	6

On Cash Creek, which enters the Little Missouri from the east about 12 miles above Yule, a lignite seam 8 feet thick is exposed near the J. S. Blue ranch.

Lignite occurs on Bacon Creek, a tributary which flows eastward near the southern border of Billings County. A seam with a thickness of at least 29 feet is mined at the T-Cross ranch about 7 miles above the mouth of the creek. The lignite outcrops in the side of the valley near the ranch buildings and is overlain by 8 to 10 feet of clay. The bottom of the seam is not exposed, and the thickness given above is only that portion which lies above the bed of the stream. Eight miles to the southeast, in Bowman County, another thick seam occurs at the Dukorn & Gamble ranch on Coyote Creek. The entire thickness could not be measured, since the bottom was concealed by talus, but 12 feet of lignite are exposed.

In Bowman County the bluffs bordering the Little Missouri rise only about 80 feet above the river and are for the most part covered with vegetation. Outcrops are therefore scarce, but where the river has cut into the bluff, forming steep, bare cliffs, no lignite seams occur. From the data at hand it seems that there is little or no lignite along the river in this county.

Lignite along the valley of Little Missouri River between Medora and Missouri River.—Throughout this region the beds are so nearly horrizontal that the river channel falls continually lower with respect to particular horizons as it extends to the north. In the vicinity of Medora the bluffs are from 200 to 300 feet high, while north of the Killdeer Mountains the level of the upland plain is between 500 and 600 feet above the river. On account of this horizontality of the rocks and the descent of the stream, the beds of lignite which were observed occur in various parts of the stratigraphic column. Although they are scattered through the great mass of sediments somewhat irregularly, there appear to be six distinct horizons at which considerable quantities of lignite were seen. These are shown in the following table:

Lignite seams along the valley of Little Missouri River between Medora and Missouri River.[a]

Location of outcrop.	Thickness of seam.	Elevation of outcrop above river.	Materials above and below lignite.	Extent of outcrop.	Remarks.
GROUP A.	*Feet.*	*Feet.*			
Medora	8	50-60		7 rods	8 seams of coal reported from this point.
4 miles north of Medora; Burgess's ranch.	10	225	Clay	2 rods	This seam probably above those at Medora.
Burgess's	1-5	100±			Probably the same as at Medora.
GROUP B.					
Opposite Burgess's house	3-8	0-16	Clay	Several rods	
5 miles below Burgess's	3-5	20-30	Clay and sandstone.	At intervals for miles.	Strata undulating.
Near Young's ranch	2-4	40-60	Clay	Seen in ravines	
Between Young's and Johnson's.					Several thin seams.
GROUP C.					
3 miles south of Mikkleson	2	0	Alluvium above.	1-2 miles	Probably other seams cut away above by the river.
1 mile south of Mikkleson	16	([b])	Clay—thin covering.	50 rods	Lowest seam may be equivalent to one 3 miles south of Mikkleson.
2½ miles below Mikkleson	16	2	Clay	15 rods (1 mile below, 10 rods).	Coal is burned in many places.
Read's ranch, 7-8 miles north of Mikkleson.	[c]4 [d]6-7	60 50-60	Sandy clay	½ mile; all bluffs along the river below Mikkleson	Sandstone below lignite in some places.
GROUP D.					
Beaver Creek, 10 miles above mouth.	10-12	([e])	Seams separated by clay and sandstone.	20 rods and ½ mile.	10-foot seam reported from this vicinity.
½ mile north of Read's ranch.	3	0	Sandstone above.	Seen at several points for a mile or more.	Two thin seams above this may represent the seams at Read's.
Opposite Morgan's ranch, 6-7 miles below Read's.	6-8	20-30	Sandy clay above; clay containing iron concretions below.	4 rods	Two other seams below this one, of 2½ and 3 feet, respectively.
Just above the mouth of Beaver Creek.	3-4	30-40	Sandy clays	1 mile	These seams were followed 6 miles down the river.
GROUP E.					
14 miles north of Beaver Creek, near Bolan Creek.	3 4 5 10	80-90	Clays, sandy clays.	Several rods in each case.	The lower seam belongs to Group E. The upper three probably belong to Group D.

[a] Wood, L. H., Third Bienn. Rept. Geol. Survey North Dakota, pp. 103-108.
[b] Four seams; lowest at water level.
[c] In bluff.
[d] In draw.
[e] Four seams above water level.

Lignite seams along the valley of Little Missouri River between Medora and Missouri River—Continued.

Location of outcrop.	Thickness of seam.	Elevation of outcrop above river.	Materials above and below lignite.	Extent of outcrop.	Remarks.
GROUP E—continued.	*Feet.*	*Feet.*			
6-7 miles below Bolan Creek, on Redwing Creek.	10	100	....	Several rods......	Probably same as the 10-foot seam at Bolan Creek.
6-8 miles below Redwing, on Squaw Creek.	5	150-200	Sandy clay...	.....do............	Seam runs on north at high levels for 10 miles.
GROUP F.					
11-12 miles north of Killdeer Mountains.	11	0	Clay..........	10 rods...........	
Near mouth of Jim Creek...	6-8	0	.....do........	5 rods............	
2 miles below Jim Creek.....	8	0	.....do........	20 rods...........	A very handsome outcrop.
Manning's ranch, 5 miles below Jim Creek.	6-8	20-30	Very fine firm clay.	40 rods...........	This coal seam is burning.
3 miles below Manning's ranch.	5	40	Yellow clay..	Several rods......	Seam probably extends several miles farther.

Lignite on Big Box Elder Creek, Custer County, Mont.—Work along this creek was confined to the lower portion of its course. Near the confluence of Coal Bank and Big Box Elder creeks, about 1 mile above the South Dakota line, a seam of lignite 11 feet thick is exposed. The outcrop extends 200 feet along Coal Bank Creek, the lignite being covered by 8 to 10 feet of gravel and sand and lying 6 feet above the water. Six or seven miles above this point and not far from the Mill Iron ranch, a cut bank on Big Box Elder Creek shows the following section:

Section near Mill Iron ranch on Big Box Elder Creek.

	Ft.	in.
Gravel and silt..	6-8	
Lignite..	5	3
Sandy clay...	2	
Lignite..	1	6
Clay, to water level...	1	

Mining is done in winter when the creek is frozen so that wagons can be driven on the ice, and the lignite is used by the neighboring ranches. In the higher buttes, which form part of the divide between Horse and Big Box Elder creeks, about 4 miles north of the Mill Iron ranch, two seams of workable thickness occur. One lies near the base of the butte and is 6 to 7½ feet thick; the other is about 125 feet higher and has a thickness of 8 feet. In the vicinity of Ekalaka, 18 miles to the west, lignite is mined at a number of points and seams 4 to 9 feet thick are found.

One or two workable seams occur in the Long Pine Hills, just west of the Montana-South Dakota line, only a few miles from Camp Crook, S. Dak. Five miles northwest of town, on the land of Mr. Hoag, a small opening has been made in a 5-foot seam, separated from a lower seam 1 foot thick by 10 inches of clay. Not over three-fourths of a mile from this point, on Mr. Owen's place, a 6-foot seam of lignite has been mined for use in Camp Crook. The lignite lies well toward the base of the hills and appears to have considerable extent.

Lignite in South Dakota.—Lignite in South Dakota is confined almost wholly to Butte County, although a few thin seams are reported to occur on the Standing Rock Indian Reservation. On the Little Missouri, about 12 miles below Camp Crook, a 6-foot seam outcrops along the river and coal is obtained here by the ranchmen of the region.

At a number of points in the Slim Buttes workable seams of lignite are exposed. At the north end two 5-foot beds are present, the lower lying 110 feet above South Fork of Grand River and separated from the upper seam by 260 feet of sand and clay. On the west side, 5 or 6 miles from the north end of the butte, in sec. 12, T. 18 N., R. 7 E., a seam 10¾ feet thick outcrops, and in sec. 23 of the same township and range two beds occur, one 4½ to 8 feet thick and the other 5½ to 6 feet.[a] A lignite bed 6 to 8 feet thick is reported to occur 8 miles east of Reva post-office and another 15 miles east.

Several good lignite seams are found on Big Nasty Creek, which has its source in the Cave Hills and flows southeastward into South Fork of Grand River. Two and one-half miles south of the Howard ranch coal is mined in sec. 2, T. 20 N., R. 8 E. The section here is as follows:

Section 2½ miles south of the Howard ranch.

	Ft.	in.
Clay	8-14	
Lignite	8	6
Sandy clay	1	
Lignite	5	6
Brown clay		3-4
Sandstone ledge	1	
Fine sand	4	

The lignite here exposed is of good quality. At the Bond place, 10 miles above the Howard ranch, a 7-foot seam occurs, separated by 9 inches of clay from a 3-foot seam. A lignite bed over 7 feet thick and of excellent quality is exposed on the Riley ranch, on the northeast side and near the base of the Cave Hills. The lignite lies only a few feet above the creek level and is overlain by 2 to 5 feet of clay. A bed 4 feet thick outcrops several miles north of Ludlow and at other localities in the Cave Hills.

Lignite is present at various points along North Fork of Grand River, which flows eastward near the boundary line between North and South Dakota. It outcrops 2 miles west of Haley, N. Dak., where a seam 6½ feet thick is exposed for 300 to 400 yards in a cut bank, the coal lying 4 to 6 feet above the river. Lignite is also mined 4 miles above this place, the bed being 5 to 6 feet thick. It is reported to occur at other localities on the North Fork, both above and below Haley. In the vicinity of Seim, near the junction of North and South forks of the Grand, lignite is plentiful. A 5-foot seam is exposed on Anderson's ranch, about 6 miles west of the reservation fence and several miles from Seim.

Lignite along Yellowstone River below Miles City.—In the vicinity of Glendive, Mont., a bed of lignite 6 feet thick occurs in the bluffs 1 mile northeast of town. The lignite is in two seams, each 3 feet thick and separated by 12 inches of clay. The Sims mine is opened in these seams and the product is of good quality. Much of the lignite used in Glendive comes from the Snyder mine, 8 miles north of town, being hauled in by teams. The seam is 8 feet thick and in the immediate vicinity there are three others of workable thickness, as follows:

Lignite beds near Glendive, Mont.

	Feet.
300 feet above the river	7
250 feet above the river	8
150 feet above the river	14
90 feet above the river	10

The lignite in the two upper beds is of excellent grade and considerable areas are underlain by it, as shown by the outcrops. On the west side of the Yellowstone, 12 miles above Glendive, at the Kinsey ranch, near the mouth of Clear Creek, a seam of lignite over 4½ feet thick has been mined where it outcrops in the hillside about 200 feet above the river.

Across the river from Fallon, about 3 miles northeast of the railroad station, a seam varying in thickness from 8½ to 10 feet is exposed at intervals for a distance of over 1 mile. At the west end of the outcrop the lignite contains several clay bands 3 to 8 inches thick, but farther east there is only one, near the top of the bed. Two miles above the Fallon ferry, at the mouth of Cottonwood Creek, a lower seam outcrops with a thickness of 6½ feet. At this point the lignite lies 5 or 6 feet above the river; but one-half mile below, it is at water level. Near the mouth of O'Fallon Creek, on the land of Mr. Gifford, the following section is exposed in the river bank:

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[a] Todd, J. E., Bull. South Dakota Geol. Survey, No. 2, p. 53.

Section near mouth of O'Fallon Creek.

	Ft.	in.
Clay	4-5	
Lignite	1	10
Clay	5-8	
Lignite	3	4
Clay	6-8	
Lignite	2	
Clay	0-4	

These seams probably underlie a large part of the extensive flat on which Fallon is located. About midway between Fallon and Terry, on the same side of the river, a seam of lignite 5 to 6½ feet thick occurs 12 feet above water level. In the river bluffs in the vicinity of the Blatchford station two seams of lignite are present. They are separated by 8 to 10 feet of clay, and are 5 to 6 and 6 to 7 feet thick, respectively. They are well exposed in the side valley extending back from Townsend ranch. At least one of these seams is found outcropping at intervals in the lateral ravines for a distance of 10 miles.

Lignite has been mined about Miles City for many years, the seams which have been worked varying from 18 inches to 4½ feet in thickness. The mines at present in operation are 5 miles from the city, the lignite being hauled by teams. The Kircher Brothers' mine, located 5 miles to the northeast, has been opened for seven years. The seam varies in thickness from 4 feet 2 inches to 4 feet 6 inches. The lignite is of excellent quality, black, lustrous, and brittle. At the Weaver mine, about the same distance from town, a 4-foot seam is being worked. Lignite is also mined on the west side of the Yellowstone, on Sunday Creek.

West of Miles City lignite is found along Cottonwood and Sarpy creeks, on the Crow Indian Reservation, near Forsyth, and at various points between Forsyth and Miles City.

On Beaver Creek, about 2 miles north of Wibaux, near the eastern boundary of Montana, a seam of lignite 11 to 12 feet thick outcrops at several points for a distance of a mile or so. It lies near creek level, and is overlain by 30 feet of soft sandstone and gravel. The seam doubtless has a considerable extent beneath the rolling plain east of the valley of Beaver Creek. Fifteen miles east of Wibaux, in North Dakota, a thick seam of coal occurs near the base of Sentinel Butte, 3 miles from the railroad station of the same name. The bed is over 21 feet thick and is mined for use in the town.

DEVELOPMENT.

Lignite is mined quite extensively at a number of localities, the larger mines being, of course, near the railroads. The lignite field is traversed east and west by the Great Northern and Northern Pacific railways; the Minneapolis, St. Paul and Sault Ste. Marie Railway, commonly known as the Soo, enters it near the northeastern border, and the Burlington and Missouri River Railroad near the southern and western borders.

In North Dakota there are large mines, many of them well equipped, on the Soo road near Burlington and Kenmare, Ward County, and at Wilton, north of Bismarck, also at Lehigh, Sims, and New Salem, on the Northern Pacific Railway. In Montana the most important mines are located near Glendive and Miles City, and in Wyoming much lignite is mined near Sheridan.

Besides the larger mines on or near the railroads there are hundreds of localities all over the area where lignite is mined on a larger or smaller scale. Throughout the greater portion of the area lignite is the only fuel used, and the ranchmen occasionally haul it 10 or 15 miles. Usually, however, there is a seam near by from which a supply may be obtained. It is generally taken from some outcrop where it can be gotten with the least amount of labor. When the seam lies near the surface the lignite is reached by stripping, or if it is exposed in a cut bank or steep bluff it is removed from the face of the outcrop with the pick or by blasting.

With few exceptions, the roof over the lignite is clay or sometimes soft sandstone, and timbering is necessary, at least in the entries. But where the seam is thick enough 6 inches to 2 feet of lignite is left, and this usually makes a safe roof, which may require no supports.

COAL AND OIL IN SOUTHERN UINTA COUNTY, WYO.

By A. C. Veatch.

INTRODUCTION.

The following report is a brief preliminary statement of a portion of the results of surveys made by Alfred R. Schultz, Max A. Pishel, and the writer, during the summer of 1905, in Tps. 12 to 23 N., Rs. 115 to 121 W., inclusive, Uinta County, Wyo. Since the investigation was primarily an economic one, concerned principally with coal and oil; since coal lands can be acquired only in "legal subdivisions, as made by the regular United States [Land Office] survey," and since the petroleum "placer claims" in this region are always entered by legal subdivisions, it was considered imperative to do the work from a land-subdivision standpoint rather than as an abstract piece of geographic and geologic mapping. Such a method is necessary in all regions having the rectangular subdivisions of the General Land Office, to render the economic results immediately available both to the investor and to the Land Office.

Land lines were carefully followed, and geologic and sketch topographic maps prepared on a scale of 2 miles to the inch, with a contour interval of 100 feet. These separate field township sheets, covering an area slightly larger than the Wyoming portion of Pl. X, are now being compiled into a single map on a scale of 1 inch to the mile. This map will show all the land corners found in this examination, and enable anyone to determine at a glance the degree of accuracy of any location under consideration. It will be used as a base for the several maps which will accompany the complete report now in preparation. These will show areal geology, structural geology, location of coal beds, and depth of principal beds throughout the area underlain by them; also depths to the oil-bearing shales in the regions where they may be found. This detailed report will probably be ready for distribution in the spring of 1907, and the reader is referred to it for an elaboration and amplification of the points here outlined and of the sketch maps here presented.

STRATIGRAPHY.

The fossils collected by this party and studied by Stanton, Girty, and Knowlton, as well as the material collected by former expeditions, indicate that the several formations observed and mapped in the field have the geologic time values shown in the accompanying table.

Succession and age of beds in southern Uinta County, Wyo.

Age.	Formation or group.	Character of strata.	Where exposed.	Thickness.	Economic value.
Quaternary.		Terrace, flood plain, and hill-wash phenomena.	Throughout area.	*Feet.* 0-300	Clayey deposits derived largely from the weathering of underlying shale beds have been used for brick near Glencoe.
		Unconformity.			
Pliocene or Pleistocene.	Wyoming conglomerate.	Multicolored pebbles in a light-gray sandstone matrix.	Not typically developed in this area. Suggested by gravels capping high hills northeast of Hilliard.	0-50	
		Unconformity.			
Eocene.	Bridger.	Greenish sands and clays, with occasional white bands. Contains a large mammalian fauna.	Portion of area southeast of Union Pacific Railroad.	*a* 1,800	
	Green River.	Light-colored, thin-bedded shales, with abundant fish remains.	Between Hams Fork and Rock Creek; about headwaters of Twin Creek; east of Meridian anticline.	*b* 2,000	
	Wasatch.	Variegated yellow and red sandy clays, with irregularly bedded white and yellow sandstones. Contain some mammals.	Throughout area.	+1,500	Yields oil and flowing sulphur water at Fossil; but oil has clearly leaked through fault from underlying Cretaceous beds. Yields flowing water of good quality on Bear River above Evanston.
		Unconformity.			
		"White beds," composed largely of volcanic ash, but containing thin limestone layers with fresh-water shells.	Yellow Creek, Bear River, Dry Hollow, and Bridger Creek.	+2,500	
		Conglomerates, sandstones, and reddish-yellow sandy clays. Typically exposed east of Almy.	Throughout area near contact of Wasatch and older rocks.	2,100	
(?)	Evanston.[c]	Gray and yellow clays, with irregular sandstone beds containing Almy coal and several minor coal beds. Characterized by plants which are distinctive of the upper Laramie beds, and by invertebrates which are common to the Laramie and Fort Union. Rests on Bear River and Jurassic beds.	From Evanston, 10 miles north.	1,500	Contains coal mined at the Evanston (Almy and Red Canyon) mines. The main coal seam has been reported as much as 33 feet thick, but it contains much bone, and for present purposes may be regarded as having a thickness of 18 feet, workable in two benches.
(?)					

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[a] Measured by W. D. Matthew and Walter Granger.

[b] Estimated by Clarence King.

[c] C. A. White, in Eleventh Ann. Rept. U. S. Geol. and Geog. Surv. Territories, 1879, pp. 240-241, used the name "Evanston coal series" in referring to the coal-bearing beds at Almy below the Wasatch and above the Bear River. Lesquereux (Sixth Ann. Rept. Geol. Surv. Territories, 1873, p. 409) has used the name "Evanston deposits."

Succession and age of beds in southern Uinta County, Wyo.—Continued.

Age.	Formation or group.	Character of strata.	Where exposed.	Thickness.	Economic value.
Cretaceous.		Unconformity.			
	Laramie.	Gray and brown clays, with irregularly bedded brown sandstones and numerous coal beds. South of Hodges Pass tunnel there is at the base of this formation a prominent white sandstone 100 to 200 feet thick. Immediately above this is the Adaville-Lazeart coal, 10 to 84 feet thick, and immediately above this coal the beds contain plants and invertebrate remains of uppermost Montana type. The overlying strata contain typical lower Laramie leaves. Top not exposed.	Along west side of Mammoth Hollow from Lazeart mine to Clear Creek and from Little Muddy to Hams Fork.	*Feet.* +5,000	Contains many beds of coal of workable thickness. The Adaville coal has been opened at Adaville (84 feet thick), Lazeart (35 feet thick), and Carlton (22 feet thick). The Hodges Pass tunnel, 1,400 feet long, cut seven coal beds varying in thickness from 5 to 26 feet. Farther west the Twin Creek mine tunnel, 1,400 feet long, cut six beds, 5, 2, 8, 10, 5, and 15 feet thick, respectively.
	Montana.	Gray to black sandy shales and shaly sandstones which weather readily and produce a region of low relief, Mammoth Hollow, affording few exposures. West of Frontier and 3,000 to 3,500 feet above the base of the formation there are several thick lenses of white sandstone. These contain numerous specimens of large *Inoceramus exogyroides*, a species characteristic of the basal Niobrara or upper Benton in the Cretaceous east of the Rocky Mountains.	Along Mammoth Hollow and near Hilliard.	6,500	Is not known to contain coal of economic importance. Carbonaceous matter has been observed at several points, and coal is reported in the Baker well near Spring Valley, 940 feet above the Kemmerer coals. This well was drilled with a cable rig, and little is known accurately of the thickness and character of the coal.
	Colorado.	Alternating beds of yellow and gray sandstone and clays with numerous coal beds. Forms pronounced parallel ridges or hogbacks. Contains distinctive Benton fossils; 400 feet from top of formation is a pronounced bed of coarse sandstone, occasionally conglomeratic, containing numerous large oysters. This is the "Oyster Ridge sandstone."	At Hilliard; east of Mammoth Hollow; west of Mammoth Hollow, between Clear and Muddy creeks.	2,400	Contains Kemmerer, Willow Creek, Carter, and Spring Valley coals. The Kemmerer coals are extensively mined at Frontier, Diamondville, Oakley, Glencoe, and Cumberland. Contains beds of sandstone of good quality, used for building purposes at Kemmerer. Quarry between Waterfall and Oakley.
		Black and gray shales containing abundant fish scales; commonly weathering silvery gray.	Between Oyster Ridge and Meridian anticline; near Millis and Knight.	1,800	Contains oil developed in wells northeast of Spring Valley. Probable source of oil in Hilliard, Carter, and Fossil oil springs.
	Bear River.	Black shales and shaly sandstones containing abundant invertebrate fossils and several thin beds of impure coal.	East of Oyster Ridge; near Hilliard; at many points between Evanston and Beckwith.	*a* +2,400	Attempts have been made to develop coal beds in this formation at Sage and Cokeville. Beds too thin and impure to be of value.
		Red, yellow, and reddish-yellow shales and sandstones, often containing thick reddish conglomerate beds.	Along Meridian anticline; west of Absaroka fault; west of Rock Creek anticline.	*b* 5,500	Has been extensively prospected for copper, and near center of overturned syncline at the Cockscomb, T. 19 N., R. 120 W., a small showing of carbonate has been found in a yellow sandstone containing some carbonaceous matter.

[a] This is the thickness found on the west side of this area. On the east side, along the Meridian anticline, the formation is often only 100 feet thick.

[b] Thickness west of Rock Creek. To the south the beds thin rapidly and the total thickness of the Jurassic in the Uinta Mountains is probably less than 1,000 feet.

Succession and age of beds in southern Uinta County, Wyo.—Continued.

Age.	Formation or group.	Character of strata.	Where exposed.	Thickness.	Economic value.
Jurassic. (?)		Black and gray shales and shaly limestones, with occasional beds of yellow sandstone, the whole containing numerous characteristic marine upper Jurassic fossils.	Rock and Twin creeks.	*Feet.* [a]3,600	The oil in the Pittsburg-Salt Lake Company's well in sec. 10, T. 14 N., R. 118 W., seems to come from this horizon.
Triassic?		Yellow, thin-bedded sandstones, weathering dark brown.	Rock and Twin creeks.	1,300	
		Red sandstones and shales.	Rock and Twin creeks; best exposed about Nugget Station.	600	
"Permo-Carboniferous."		Gray cherty limestones and yellow sandstones containing an abundant and characteristic "Permo-Carboniferous" fauna.	Rock Creek, Absaroka Ridge, west of Cumberland.	2,500	
		Red shales and sandstones.	Rock Creek.	750	
		Gray to white sandstones, sometimes calcareous and often brecciated. Base not seen.	Rock Creek.	+1,000	Has been prospected for copper, and just north of Watercress Canyon, T. 22 N., R. 118 W., a showing of carbonates has been found.
Pennsylvanian (Upper Carboniferous).		Hard black and blue-gray cherty limestones containing Upper Carboniferous fossils. At no place were these rocks seen in contact with the sandstone mentioned above.	Along Bear River from the Narrows intermittently to Cokeville.	Not determined.	

[a] Thickness west of Rock Creek. To the south the beds thin rapidly and the total thickness of the Jurassic in the Uinta Mountains is probably less than 1,000 feet.

STRUCTURE.

The disturbances of the strata in this area are traceable to two periods—late Cretaceous and early Tertiary.

(1) Near the close of the Cretaceous period, between the Laramie and Evanston, the main folding of this region took place, producing the Meridian anticline, Lazeart syncline, Absaroka fault, Rock Creek anticline, and associated structural features. (2) On the eroded edges of these upturned beds the Evanston beds were laid down, and some time after the deposition of the lower Wasatch conglomerates, movements along several of the old lines of deformation tilted and faulted these younger beds, producing in some cases very high local dips, often in directions opposite to those of the older beds. These phenomena are of considerable importance in indicating the directions of thrust. The more important of these disturbances of the Eocene beds are traceable to movements along the Absaroka fault, the Rock Creek–Needles anticlinal, and a secondary fault line along Bear River, north of Evanston.

The important structural features in the pre-Evanston beds in this area are from east to west (see Pls. X and XI): (1) A rather regular anticline—the Meridian anticline; (2) a somewhat disturbed, and in places overturned, syncline—the Lazeart syncline; (3) a much broken region lying between this syncline and the fault to the west; (4) a large and very persistent faulted anticline, with a downthrow to the east—the Absaroka fault; (5) a somewhat disturbed synclinal basin, deeply filled with Tertiary material, lying between the Absaroka fault and the uplifted and disturbed region toward the west; (6) a greatly disturbed region, which in its broader features, consists of a somewhat broken anticline of "Permo-Carboniferous" and Jurassic beds, whose westward flank is broken by a number of minor irregular folds and faults; and (7) a folded and faulted mass of Upper Carboniferous rocks—the Crawford Mountains.

The Meridian anticline is almost wholly buried by Tertiary beds, which, as they dip eastward across the whole anticline, give no clew to its position. The crest of this anticline is exposed in the valley of Little Muddy Creek, 3 or 4 miles east of Cumberland and east of Frontier, where it shows dips to the east of about the same amount as those to the west. The inferred positions of the coal beds and oil-bearing shale on its east side (Pls. X and XI) are based wholly on the assumption that this is a simple anticline. To the north it shows some tendency toward complexity, with one or more secondary folds to the east, and this complexity may extend farther to the south.

Near Hilliard the Lazeart syncline is entirely overturned, the lower limb dipping westward at angles of from 25° to 30°, and the upper limb at from 90° to 130°. Between Hilliard and the Aspen tunnel it returns to a normal syncline, with dips of 20° to 30° on the east and 40° to 75° on the west. At Round Mountain it is again overturned and perhaps faulted, but from that point northward it appears entirely normal, with dips on the west side commonly more than double those on the east. The Laramie beds which occur along the deepest parts of this syncline are broken by the rising and pitching of the syncline into three basins—at Hilliard, between Lazeart and Round Mountain, and between Little Muddy Creek and a point 2 miles north of Hams Fork.

Between the Lazeart syncline and the Absaroka fault the beds are greatly disturbed, the amount of disturbance increasing with proximity to the fault line.

In the Absaroka fault the displacement is something over 15,000 feet, with the downthrow to the east. In the Absaroka Ridge region there is some folding west of the fault line, but beyond this the beds dip westward, indicating that the area between the fault and the overturned Rock Creek anticline is a broad syncline. On Sulphur Creek and about Knight the Jurassic beds just west of the fault suggest a closely compacted anticline, merging toward the west into an overturned syncline (Pl. XII, *A*). The eastward-dipping Bear River beds and the coals near Old Millis siding (on Sulphur Creek, due south of Knight) are clearly on the upper or eastward flank of an overturned syncline.

Of the disturbed region along the west of the Rock Creek-Needles anticlinal, little need be said in this paper, since, with the exception of the beds of Evanston age, containing the Almy coals, the formations here are all Bear River or older, and hence lie below the main coal measures of this region. The formations are also older than the beds yielding oil at Spring Valley, and are, moreover, too badly broken to be of probable importance from an oil standpoint. The Almy coals are found on the east side of a minor faulted anticline on the west side of the Rock Creek-Needles anticlinal.

COAL.

Coal developments have been made in four different groups of coal-bearing beds—(1) the Bear River formation; (2) a group containing the Kemmerer, Willow Creek, Carter, and Spring Valley coals, of Benton age; (3) a group containing the Adaville and Twin Creek coals, of uppermost Montana and Laramie age; and (4) the beds of upper Laramie or Evanston age at Almy.

Coal of the Bear River formation.—Peale[a] reports that coal was discovered near Sage in 1875, and that before his visit in 1877 a mine had been opened by the Wyoming Coal and Coking Company and coke ovens erected. The slope was 470 feet in length, with a single side entry 120 feet long. He reports the following section:

Section of coal-bearing strata at Sage, Uinta County, Wyo.

	Feet.
1. Light-colored sandstone, forming roof.	
2. Coal, mined by Wyoming Coal and Coking Company	6
3. Clay	3-6
4. Coal	0.3
5. Shales and slate.	
6. Coal	3.5
7. Sandstone, with thin bed of coal.	

It is reported that picked samples of this coal will make coke and that washing was tried to remove the impurities. With the building of the Oregon Short Line in 1881 a second attempt was made to develop this locality, and a third trial was made in 1890, when, it is reported, the old slope was deepened about 200 feet and several new entries were driven. A new coke oven was constructed under the direction of a Pennsylvania expert, who, after careful tests, pronounced the coal of no value as a coking coal. Altogether about $130,000 has been spent in a fruitless attempt to develop the coal at this point.

This mine is still open, although the lower part is filled with water. An examination of the coal bed near the mouth of the mine showed 5½ feet of very impure coal.

Stanton has shown that the upper coal here is above beds containing marine lower Colorado fossils, while the beds adjoining the lower coals contain typical Bear River species.[b] Similar coals are found in the Bear River formation at Cokeville (formerly called Coketown), 20 miles north of Sage, and attempts to develop these beds have likewise proved fruitless. Prospects have been opened just east of Beckwith in the same beds which occur at Sage.

Coal-bearing beds containing the Kemmerer, Willow Creek, Carter, and Spring Valley coals.—The coals in this group were first discovered by Frémont near the present site of Cumberland, August 19, 1843.[c] In 1848 Clayton[d] reported coal in these beds on Sulphur Creek near the site of old Bear River City, and in 1852 Stansbury described the locality and placed on the map accompanying his report the words "Great Coal Basin," extending from the

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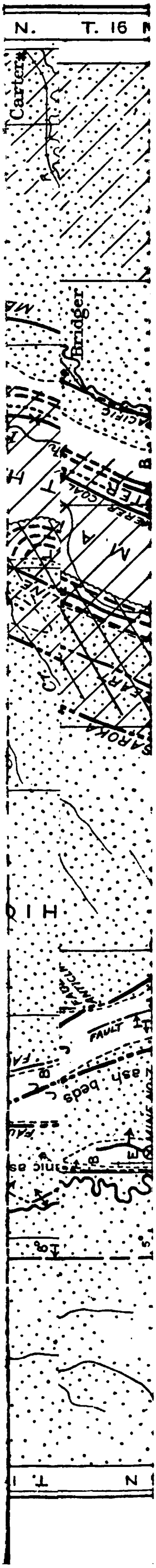
[a] Peale, A. C., Report on the geology of the Green River district: Eleventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr. (for 1877), 1879, pp. 574-575.

[b] Am. Jour. Sci., 3d ser., vol. 43, 1892, p. 108.

[c] Frémont, J. C., Report of the Exploring Expedition to Rocky Mountains and to Oregon and North California, 28th Cong., 2d sess., House Doc. No. 166, 1845, pp. 131, 297.

[d] Clayton, W., Latter Day Saints Emigrants' Guide, 1848, p. 29,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west bank of Bear River, near the present city of Evanston to Point of Rocks, Sweetwater County.[a] The beds at this point were opened about the time of the building of the Union Pacific Railroad in 1869, but were never worked to any great extent.

In 1859 a United States military coal reservation was established at a point about 3 miles east, in beds of the same age, but this coal also was but little worked, although it is probable that small amounts were hauled to Fort Bridger for blacksmithing purposes.

The first important mine in these beds was that of the Diamond Coal and Coke Company at Diamondville, opened in 1894. Subsequently mines were opened by the same company at Glencoe and Oakley. The Kemmerer mines were opened in 1897, by the Kemmerer Coal Company, and the Cumberland mines by the Union Pacific Coal Company in 1900, the year in which this company finally abandoned its Almy mines. All these mines develop the main Kemmerer bed, which varies in thickness in the workings from 5 to 20 feet. At some points between these mines, along the outcrop, the bed is very thin or even absent. At Diamondville a coal about 5 feet thick and about 50 feet above the main bed is worked to a small extent, and at Kemmerer a bed 6½ feet thick has been opened 15 feet below the main bed.

The Willow Creek coal is about 550 feet below the main Kemmerer coal. It is thin or absent in the south end of the field, but reaches a thickness of 5 feet 8 inches in T. 22 N., R. 115 W., where the Kemmerer Coal Company proposes to open a mine. Tests of this coal have yielded a coke of fair quality, and it is for its coking value that this coal is to be developed.

The Spring Valley coal is 1,475 feet stratigraphically below the Kemmerer coal. A mine was opened in this bed at Spring Valley by the Union Pacific Coal Company in 1899, but the mine was abandoned in 1905. The bed here is from 5 to 6 feet thick, with several irregular partings. The coal is rather dirty, and the mine was finally abandoned because of the bad roof and gas. The Carter coal seam is 175 feet above the Spring Valley bed, and is 7 feet 9 inches thick, with two partings having a total thickness of 1 foot 7 inches. It has been worked to a limited extent in the Carter opening at Spring Valley. A small mine northeast of Hilliard develops one of this group of beds and supplies a limited amount of coal for local use. Openings have also been made in sec. 12, T. 15 N., R. 118 W., to supply fuel for drilling neighboring oil wells.

The approximate outcrop and the area underlain by these coals is shown in Pl. X. They outcrop along the west flank of the Meridian anticline throughout the area and on the west flank of the Lazeart syncline in the region of Altamont, between Clear Creek and a point 2 miles north of Little Muddy and north of Hams Fork. On the east side of the syncline the dip is from 8° to 35° and on the west it is generally over 45°. Near the Absaroka fault the beds, while coal bearing, are so badly broken that they are of little commercial importance. This is notably the case at Altamont. The amount of coal in sight in this basin is very large, and although the beds are somewhat irregular mining will be carried on here for many years.

Coal-bearing beds containing the Adaville and Twin Creek coals.—From an early day this coal-bearing group has been noted for the great number and thickness of its coal seams. Peale reports that the Smith and Bell Brothers in 1876 discovered and opened in the region of Hodges Pass on the divide between Twin Creek and Hams Fork twenty-nine beds of coal, ranging in thickness from 1½ to 48 feet and aggregating 315 feet.[b]

On the completion of the Oregon Short Line the Union Pacific Coal Company opened mines a mile west of Hodges Pass tunnel. Mine No. 1 was opened in 1881 and No. 2 in 1882.

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[a] Stansbury, Capt. Howard, Exploration and Survey of the Great Salt Lake of Utah, 1852, pp. 226, 280.

[b] Peale, A. C., Report on the geology of the Green River district: Eleventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr. (for 1877), 1879, p. 535. Peale states that the twenty-nine beds occurred in a thickness of three hundred and fifteen feet, which is incorrect; but a statement that the aggregate thickness is three hundred and fifteen feet is quite within the facts now known, and was probably the actual statement made by his informant.

In mine No. 1 a horizontal prospect tunnel 1,400 feet long cut beds 5, 8, 10, 5, and 15 feet in thickness, while in mine No. 2 two beds, stratigraphically 750 feet above the uppermost bed in No. 1, were opened 120 feet apart, one 20 and the other 14 feet thick. These mines were abandoned in 1885. The Hodges Pass tunnel, 1,400 feet long, cut coal beds 9½ 38, 6, 14, 6, 5, and 6 feet thick. Three miles south of this tunnel the prospect tunnel at the Adaville opening cut a bed 84 feet thick, with a single parting of clay 2 inches thick. This mine was abandoned after one shipment of coal because the coal slacked badly, but the fact that the roof of the opening, composed entirely of coal and not timbered, is solid and of good luster after fifteen years' exposure to the air suggests that the coal may perhaps have shipping qualities. The coal exposed in this mine is on the whole a much cleaner coal than that found in the Kemmerer seam.

This lower or big vein has been opened further south, at the Lazeart mine, west of Spring Valley, and the Carlton mine, near Hilliard. The Lazeart mine was in operation in the summer of 1905, and its small product was hauled by wagons to Evanston or sold to local oil operators. At both these mines it was stated that the product crumbled badly.

Because of the rising and pitching character of the Lazeart syncline the beds of this group occupy three basins, the first extending from 2 miles north of Hams Fork to 2 miles north of Little Muddy Creek, the second from Clear Creek to the Lazeart coal mine, and the third from near Sulphur Creek southward for an undetermined distance, probably but a few miles.

This coal-bearing group contains an immense amount of fuel of fair quality, that will undoubtedly be largely developed in the future.

Almy coals.—With the completion of the Union Pacific Railroad in 1869, mines were at once opened in the coal-bearing beds at Almy, a few miles north of Evanston. The Wyoming Coal Company (later the Union Pacific Coal Company) shipped coal in 1869 and the Rocky Mountain Coal and Iron Company in 1870. The latter supplied for a number of years the coal used over a large part of the Central Pacific Railroad. Peale reports that the coal-bearing beds vary in thickness from 22 to 32 feet,[a] but these thicknesses include large proportions of bone. The workable coal is to be regarded as from 15 to 20 feet thick, and is worked in two benches. The Union Pacific Coal Company continued operations at this point until 1900, when the mines were abandoned because of fires and a change in dip in the lower part of the mines, which rendered it difficult to continue operations in the way they had been started. The Rocky Mountain Coal and Iron Company is still operating mine No. 5 on a small scale. The output is hauled from the mine by wagon and the consumption is entirely local.

The developments here have shown that the coal is of commercial thickness and quality only for about 4 miles along the outcrop. The dip is from 15° to 20°, but decreases rapidly to the east, and the trough of a small syncline is reached at a distance of a quarter of a mile from the outcrop. The surface dips indicate that this is a minor feature and that beyond a slight rise the eastward dip will continue. There is still a considerable amount of unworked coal in this area, the most of which is now controlled by the Rocky Mountain Coal and Iron Company.

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[a] Fifth Ann. Preliminary Rept. U. S. Geol. Survey of Montana, 1872, p. 194.

QUALITY OF COAL.

Ten samples of coal were collected from mines in this region. The samples were taken with great care, pulverized and quartered in the mines, and sent in sealed cans to the chemical laboratory [a] of the United States Geological Survey coal-testing plant, St. Louis, Mo., where the following analyses were made:

Analyses of coals from southern Uinta County, Wyo.

[F. M. Stanton, analyst.]

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Loss of moisture on air drying	6.90	6.70	[b]6.70	[b]14.80	2.60	1.30	2.40	2.00	1.40	2.00
Analyses of sample as received:										
Proximate—										
Moisture	14.11	14.43	19.15	22.37	6.78	5.13	5.89	5.86	3.96	6.85
Volatile matter	35.34	36.81	36.79	34.50	39.79	40.51	37.59	39.49	36.16	35.62
Fixed carbon	34.40	41.54	38.80	40.21	47.43	49.75	49.01	51.00	55.11	43.86
Ash	16.15	7.22	5.26	2.92	6.00	4.61	7.51	3.65	4.77	13.67
Ultimate—										
Sulphur	4.45	.21	1.18	.50	.43	.49	1.39	1.07	.77	.94
Hydrogen	5.30	5.37	6.13	6.10	5.56	5.63	5.28	5.57	5.17	4.99
Carbon	48.91	59.97	57.03	56.02	69.01	72.95	68.48	72.96	76.03	63.91
Nitrogen	.82	1.15	1.01	.88	1.12	1.18	1.07	1.08	1.31	1.12
Oxygen	24.37	26.08	29.39	33.58	17.88	15.14	16.27	15.67	11.95	15.57
Calorific value determined—										
Calories	4,898	5,804	5,631	5,440	6,815	7,202	6,870	7,102	7,501	6,305
British thermal units	8,816	10,447	10,136	9,792	12,267	12,964	12,366	12,784	13,502	11,349
Calorific value calculated from ultimate analysis—										
Calories	4,828	5,577	5,482	5,192	6,727	7,194	6,684	7,163	7,429	6,213
British thermal units	8,690	10,039	9,868	9,346	12,109	12,949	12,031	12,893	13,372	11,183
Thickness of coal sampled ... feet	4	24	15	84	8	7	9	6½	3	4
Name of coal bed	Almy.		Adaville.		Main Kemmerer.			Lower Kemmerer.	Willow Creek.	Spring Valley.
Geologic age	Post-Laramie.		Upper Montana.[c]		Colorado (Benton).					

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[a] Chemical laboratory in charge of Prof. N. W. Lord, of the Ohio State University.

[b] The air-drying losses in the Adaville and Lazeart coals do not appear to be entirely comparable.

[c] This is just below the Laramie coals and may be said to represent them.

I. Michigan-Wyoming Oil Company's mine, NW. ¼ sec. 35, T. 17 N., R. 120 W. Sample taken 40 feet from mouth of mine. Bone 1 inch thick 6 inches from the roof and 4 inches thick 18 inches from the roof, omitted in sampling. Sample represents total thickness of bed.

II. Rocky Mountain Coal and Iron Company's mine No. 5, Almy, Wyo. Sample taken 3,000 feet from mouth of slope in room 5, entry 12, and represents lower 8 feet of 24-foot vein. Upper part of bed contains numerous partings.

III. Lazeart mine, SE. ¼ SW. ¼ sec. 8, T. 15 N., R. 118 W. Sample taken 15 feet from mouth of slope. Bed is 30 feet thick and sample represents upper 13 feet.

IV. Adaville mine, NE. ¼ SW. ¼ sec. 20, T. 21 N., R. 116 W. This sample is from a tunnel driven horizontally across the coal bed, which is here 84 feet thick and dips 18° W. Tunnel is 6 feet high and sample was collected by means of vertical cuts every 50 feet. This sample represents slightly less than half the thickness of the bed. There are no partings and the coal is remarkably uniform throughout.

V. Union Pacific Coal Company, Cumberland No. 1 mine, Cumberland, Wyo. Sample from the face of seventh entry south, 2,100 feet west and 2,000 feet south of mouth of mine. Sample represents entire bed.

VI. Diamondville Coal and Coke Company, Diamondville No. 1 mine. Sample from room No. 45, entry No. 1 north, 160 feet west and 3,300 feet north of mouth of mine. A clay seam 4 inches thick 1 foot from roof was omitted in sampling. Coal at the point sampled is regarded as best in the mine.

VII. Kemmerer Coal Company, Kemmerer No. 1 mine, Frontier, Wyo. Sample taken from room 46, entry 3 south, 600 feet west and 2,250 feet south of mouth of mine. Sample represents a complete section of coal. No definite partings.

VIII. Kemmerer Coal Company, Kemmerer No. 1 mine, Frontier, Wyo. Sample from working face in new opening in lower bed. From mouth of mine 600 feet south, 250 feet east (this portion is a crosscut from the main seam to the lower bed), and 250 feet south of working face. Bed is 6½ feet thick and 40 feet below main bed. Band of dirt 6 inches thick 4 feet from floor omitted in sampling.

IX. Kemmerer Coal Company, Willow Creek opening, SW. ¼ NW. ¼ sec. 19, T. 22 N., R. 115 W. Sample from face of entry 150 feet from mouth of mine. Bed 3 feet thick, with no partings. Regarded by owners as a coking coal.

X. Richardson mine, NW. ¼ sec. 12, T. 15 N., R. 118 W. Sample taken 150 feet west and 50 feet north of mouth of mine. Clay seam 3 inches thick and 1 foot from floor omitted in sampling.

In order that these analyses may be compared with others which have already been made in this region, the following table has been prepared, with the analyses separated into groups according to the geological horizons of the coals. The ash and sulphur—which, while accidental impurities varying greatly from point to point in the same bed, are still of great commercial importance—have been calculated on the basis of air-dried samples. The moisture, volatile combustible matter, and fixed carbon have been recalculated on the basis of the air-dried ash-free samples.

Proximate analyses of coals from southern Uinta County, Wyo.

COALS OF BENTON (CRETACEOUS) AGE, INCLUDING THE KEMMERER, WILLOW CREEK CARTER, AND SPRING VALLEY BEDS.

Source of sample.	Ash.	Sulphur.	Moisture in air-dried ash-free sample.	Volatile combustibles.	Fixed carbon.	Calorific values.		Analyst.
						As determined.	Calculated for air-dried ash-free sample.	
J. D. Curtis, Hams Fork, prospect sample.	2.85	1.00	1.54	39.01	59.45	7,560	7,782	Slosson and Knight.[a]
William Goodell, Hams Fork, 6-foot face sample.	4.05	....	3.07	39.65	56.28	7,467	7,782	Do.
A. Kendall, Hams Fork, prospect sample.	3.60	.60	3.89	38.65	57.46	7,372	7,647	Do.
Cumberland No. 1, Kemmerer bed.	5.25	....	4.69	43.91	51.40	....	....	W. S. Robinson.[b]
Cumberland No. 2, Kemmerer bed.	5.13	....	3.69	43.22	53.09	....	....	Do.
Spring Valley No. 1, Spring Valley bed.	7.16	....	3.88	42.80	53.32	....	....	Do.
Kemmerer, main Kemmerer bed.	7.51	1.39	3.87	41.73	54.40	6,870	7,628	F. M. Stanton.
Kemerer, lower bed	3.65	1.07	4.09	41.86	54.05	7,102	7,527	Do.
Cumberland No. 1, main Kemmerer bed.	6.00	.43	4.51	43.53	51.90	6,815	7,452	Do.
Diamondville, main Kemmerer bed.	4.61	.49	4.07	43.06	52.87	7,202	7,654	Do.
Richardson, Spring Valley bed.	13.67	.94	5.09	42.53	52.38	6,305	7,530	Do.
Kemmerer, Willow Creek bed.	4.77	.77	2.73	38.54	58.73	7,501	7,994	Do.
Average of Benton coals[c]	5.69	.83	3.76	41.54	54.61	7,133	7,666	

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[a] The heating power of Wyoming coal and oil: Special Bull. University of Wyoming, January, 1895.

[b] These analyses, made in the laboratory of the Union Pacific Coal Company, were selected from many hundreds by Mr. Frank Manley, chief engineer, as typical.

[c] The averages are not entirely satisfactory in the volatile combustible and fixed carbon columns, as it is evident from a comparison of analyses that two different methods have been used in the determination of these values. The Slosson and Knight values are always higher in fixed carbon than the Stanton values, without any corresponding increase in the calorific value. Thus in the Almy coals where the moisture is the same Stanton finds a value 6,365 calories from a sample showing "Fixed carbon 44.72 per cent," while Slosson and Knight obtained a value of 6,393 calories from a sample showing "Fixed carbon 54.98 per cent."

Proximate analyses of coals from southern Uinta County, Wyo.—Continued.

COALS OF UPPER MONTANA-LARAMIE AGE, INCLUDING ADAVILLE AND TWIN CREEK COALS.

Source of sample.	Ash.	Sulphur.	Moisture in air-dried ash-free sample.	Volatile combustibles.	Fixed carbon.	Calorific values.		Analyst.
						As determined.	Calculated for air-dried ash-free sample.	
Union Pacific Coal Co., Twin Creek mines.	6.30	....	9.16	37.59	53.25	....	....	(a)
Adaville mine...............	1.18	0.50	9.20	41.93	48.87	5,440	6,612	F. M. Stanton.
Lazeart mine...............	5.26	1.18	14.14	41.79	44.07	5,631	6,396	Do.
Average of upper Montana-Laramie coals.	4.25	.84	10.83	40.44	48.73	5,535	6,502	

COALS OF EVANSTON OR POST-LARAMIE AGE, INCLUDING ALMY COALS.

Source of sample.	Ash.	Sulphur.	Moisture in air-dried ash-free sample.	Volatile combustibles.	Fixed carbon.	As determined.	Calculated for air-dried ash-free sample.	Analyst.
Almy No. 5, lower 8 feet....	7.22	0.21	10.02	42.27	47.70	5,804	6,665	F. M. Stanton.
Michigan-Wyoming mine..	16.15	[4.45]	9.36	45.92	44.72	4,898	6,365	Do.
Almy No. 6...............	6.55	.29	8.29	37.56	54.15	6,553	7,012	Slosson and Knight.[b]
Almy No. 5, lower 9 feet....	8.00	.44	8.07	39.20	52.73	6,340	6,891	Do.
Almy No. 7, upper seam...	9.00	....	8.10	38.33	53.57	6,145	6,753	Do.
Almy No. 7, lower seam...	5.90	.65	9.37	35.65	54.98	6,017	6,393	Do.
Almy No. 5, middle 2½ feet.	9.25	....	7.54	40.20	52.26	5,933	6,538	Do.
Almy, average of three analyses.	7.46	....	6.29	40.33	53.38	.. ....	.. ....	Persifor Frazier, jr.[c]
Almy.....................	8.83	....	8.85	43.42	47.73	....	....	O. D. Allen.[d]
Do.....................	8.88	....	8.88	43.04	47.08	....	....	Do.
Do.....................	6.30	....	9.15	37.59	53.26	....	....	J. V. Hodge.[e]
Almy No. 5...............	9.70	.10	9.64	44.73	45.63	....	....	J. S. Cory.[f]
Almy No. 6...............	2.80	.14	9.97	44.10	45.93	....	....	Do.
Average of Evanston coals[c]	8.16	[g].30	8.73	40.95	50.24	5,956	6,660	

[a] Mineral Resources of the United States [for 1882], U. S. Geol. Survey, 1883, p. 88.
[b] The heating power of Wyoming coal and oil: Special Bull. University of Wyoming, January, 1895.
[c] [Fourth Ann.] Prelim. Rept. U. S. Geol. Survey Wyoming and contiguous Territories, 1871, p. 184.
[d] Rept. Geol. Expl. 40th Par., vol. 3, 1870, p. 473.
[e] [Fourth Ann.] Prelim. Rept. U. S. Geol. Survey Wyoming and contiguous Territories, 1871, p. 321.
[f] Chemist in charge, Dept. Mines, World's Columbian Exposition.
[g] Omitting Michigan-Wyoming mine, which probably represents an accidental sulphur ball.

From these analyses and the general physical character of the coals, the Benton coals are to be regarded as high-grade bituminous, the Evanston coal as low-grade bituminous, and the upper Montana-Laramie (Adaville and Twin Creek coals) as high-grade black lignites.

According to the carbon-hydrogen ratio classification of coals recently proposed by M. R. Campbell,[a] these coals fall in the following groups:

The Willow Creek coal, of Benton age, falls in Group G, which includes the Upper Freeport and Pittsburg coals of northern West Virginia, Kanawha Valley coals, high-grade Kentucky coals, and Alabama coals.

The Kemmerer (Benton) coal belongs to Group H, which includes Indian Territory coals, Kansas coals, high-grade Illinois, Iowa, and Missouri coals, and second-grade Kentucky coals.

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[a] The classification of coals: Trans. Am. Inst. Min. Eng., Washington meeting, May, 1905.

The Evanston coals belong to Group I, which includes the great majority of Iowa, Illinois, Missouri, and Indiana coals, and some bituminous coals from Wyoming and Montana.

The Adaville-Twin Creek coals [a] fall in Group J with the Gallup (N. Mex.) and Boulder (Colo.) black lignites.

Slosson has already shown that from the standpoint of carbon content and calorific value the Benton coals of this region are the best coals in Wyoming. According to the analyses made at the United States Geological Survey coal-testing plant of samples collected by Fenneman and Gale in the Routt County (Colo.) field and by J. A. Taff in the Coalville and Castle Gate field in Utah, given elsewhere in this volume, the coals found in this region in the Benton are better than the best bituminous coals in these Colorado and Utah fields, but higher carbon and fuel values are shown in the latter fields in portions of the beds which have been altered to "anthracite" or "natural coke" by dikes or flows. Similarly the analyses made of the samples collected by Schrader and Shaler in the Gallup (N. Mex.) field show that on the whole the Benton coals of Wyoming are of the same grade as the best coals of that region. They are much better than the Red Lodge (Mont.) coals tested at St. Louis.[b] On the whole, the Benton coals of the Uinta County region may be said to belong near the top of the group containing the best bituminous coals of the Rocky Mountain region.

OIL.

Oil has been found in southern Uinta County in springs on Hilliard Flat (sec. 4, T. 13 N., R. 119 W., and sec. 33, T. 14 N., R. 119 W.); at Aspen tunnel (sec. 12, T. 14 N., R. 119 W., and sec. 7, T. 14 N., R. 118 W.); 3 miles north of Aspen tunnel, at Carter oil springs (sec. 31, T. 15 N., R. 118 W.); in springs and wells on the south branch of Twin Creek (T. 21 N., R. 117 W.), and in wells near Spring Valley (Tps. 14 and 15 N., R. 118 W.).

HISTORY OF DEVELOPMENT.

The oil spring near Hilliard, in the NW. ¼ sec. 4, T. 13 N., R. 119 W., was doubtless well known to the trappers who first built the trading post of Fort Bridger, but the first published account was the result of an examination made by the Mormons in their pioneer journey to Great Salt Lake in 1847. W. Clayton,[c] who accompanied this expedition, published in 1848 a little book, which was known for years as the "Mormons' Guide Book." containing the following account:

> About a mile from this place [the crossing of the road over Sulphur Creek] in a southwest course is a "Tar" or "Oil" Spring, covering a surface of several rods of ground. A wagon trail runs within a short distance of it. It is situated in a small hollow, on the left of the wagon trail, at a point where the trail rises to a higher bench of land. When the oil can be obtained free from sand, it is useful to oil wagons. It gives a nice polish to gunstocks, and has been proved to be highly beneficial when applied to sores on horses, cattle, etc.

This spring is mentioned in the accounts of Stansbury[d] and Engelmann,[e] but their statements do not differ materially from the earlier account of Clayton. It is reported that Brigham Young caused a shallow well to be dug at this point, and the locality is now known as the Brigham Young oil well or spring. The oil was skimmed off the surface of

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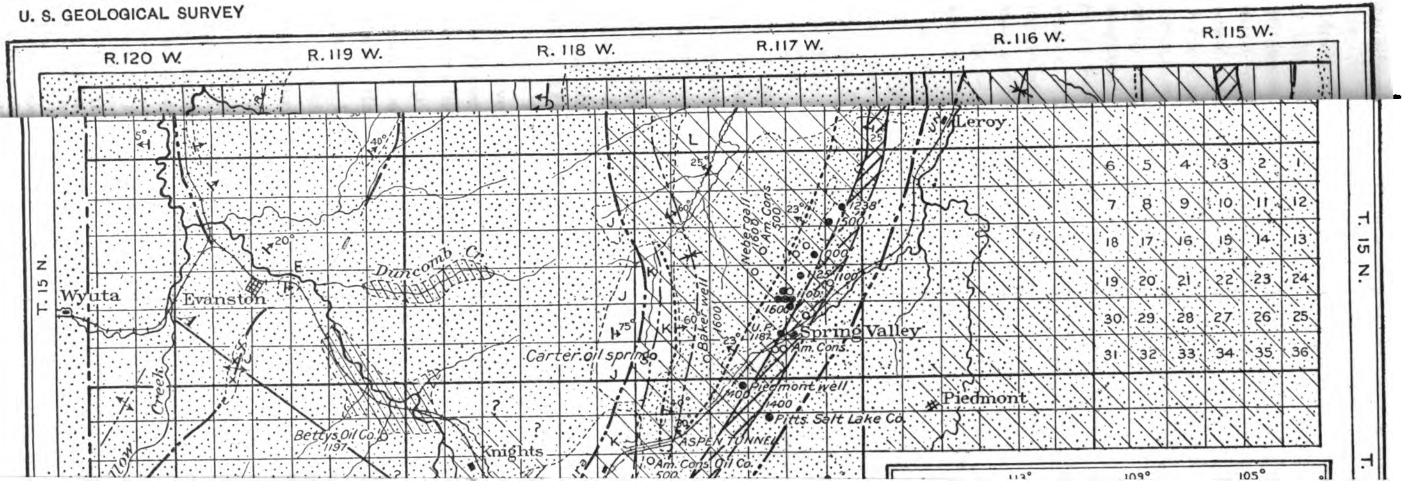
[a] Calculated on the excessive air-drying loss reported in the Adaville analyses, the Adaville coal belongs high in Group I, while the Lazeart coal belongs in Group J. According to physical characters and general fuel value, these two coals clearly belong together and are to be regarded as high-grade black lignites. An examination of the two original analyses will suffice to show that the air-drying losses reported for these two coals are not entirely comparable. New analyses are now being made.

[b] Bull. U. S. Geol. Survey No. 261, 1905, p. 49.

[c] Clayton, W., The Latter-Day Saints' Emigrants' Guide: being a Table of Distances, showing all the springs, creeks, rivers, hills, mountains, camping places, and all other notable places, from Council Bluffs, to the Valley of the Great Salt Lake, etc. St. Louis, 1848, pp. 18, 24.

[d] Stansbury, Capt. Howard, Exploration and Survey of the Valley of the Great Salt Lake of Utah, 1852, p. 280.

[e] Engelmann, H., Preliminary Report on the Geology of the country between Fort Bridger and Camp Floyd, Utah Territory, accompanying Simpson's Report on Wagon Routes in Utah Territory, 35th Cong., 2d sess., Senate Ex. Doc., vol. 10, No. 40, 1859, p. 52.


R. 120 W.
R. 119 W.
R. 118 W.
R. 117 W.
R. 116 W.
R. 115 W.
T. 15 N.
T. 15 N.
T.
Wyuta
Evanston
Duncomb Cr.
Creek
E
J
K
L
Carter oil spring
Baker well
1600
Nebergall
1600
Am. Cons.
500
1238
1500
1000
1125
1100
1100
1600
U. P.
1182
Am. Cons.
Spring Valley
Leroy
Piedmont
Piedmont well
1400
1400
Pitts Salt Lake Co.
ASPEN TUNNEL
Am. Cons. Oil Co.
500
Bettys Oil Co.
1197
Knights
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20°
40°
60°
75°
23°
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the water in this well, sold to emigrants, and carried in small quantities to Salt Lake City.

In 1867 Judge C. M. White began operations at a spring in the NW. ¼ sec. 33, T. 14 N., R. 119 W., now known as the White oil spring. He dug a large hole and skimmed off the oil, which he sent to Salt Lake and sold to tanners. He began drilling in 1867, but abandoned the hole in 1868 at a depth of 480 feet. Later the Evanston Oil Company sunk a well at this place, but it was likewise abandoned at a depth of a few hundred feet.

The Carter oil spring locality became of importance in 1868, when in driving a tunnel for coal a slight flow of petroleum (8 to 10 gallons a day) was obtained and the discharge of the spring ceased. This oil was collected and sold to the Union Pacific Railroad and to neighboring coal mines for lubricating purposes. It is reported that Judge Carter, then sutler at Fort Bridger, attempted to drill a hole here, but the well was abandoned without results. This spring was incidentally mentioned by Meek[a] in 1871 and a short statement regarding it was published by Emmons[b] in 1877, but the first account of importance is that published by Ricketts[c] in 1888.

The oil springs along the south fork of Twin Creek in T. 21 N., R. 117 W., are perhaps referred to in Lander's general statement that in the mountains along the divide in latitude 42° N. there are "beds of coal, iron, and salt, and a spring of peculiar mineral oil which by chemical process may be made suitable for lubricating machinery." At any rate, the map of his explorations in 1857 shows that he passed up Twin Creek and over Hodges Pass.[d] Operations were begun here by the Twin Creek Land and Oil Company in 1885. This company drilled before 1887 two wells, one 110 feet deep and the other 185 feet. Both yielded a large flow of brakish sulphur water, with a little oil and gas. The deeper of the two is now open and is commonly known in the field as the Clark well, from Senator C. D. Clark, who was interested in this company. The oil is dark and heavy. The gravity is given by the Union Pacific Railroad[e] as 26.75° Baumé, by Slosson[f] as 19.7° Baumé.

In the fall of 1900 the Union Pacific Railroad began a water well at Spring Valley, Wyo., and October 14 struck a white sand containing a very high-grade oil between 424 and 463 feet. Oil was struck again in December between 567 and 575 feet and the following May between 1,147 and 1,159 feet. Water is reported in this well at a depth of about 300 feet, but it was brackish and the well was capped and abandoned. Intense excitement followed this find and as the greater part of the land in this section was unoccupied Government land the whole region was soon staked out as petroleum claims under the placer-mining laws. A large part of these were purely speculative claims, which the owners had no intention of developing. The Government Land Office took the important step of removing from entry, except under the mining laws, all Government lands in an area very nearly equal to that shown on Pl. XI, and refused to issue to the Union Pacific Railroad patents for the unpatented odd sections in the railroad grant within the limits of this reservation until after December 1, 1903, when the issuance of patents was to be determined by the "then known character of the land." In the words of the Department:[g]

> The purpose of this order is to permit, encourage, and protect, so far as the Department can do so, but within the time herein named, the exploration and exploitation of the unpatented alternate odd-numbered sections within said railroad land grant which are within the limits hereinbefore specifically described, and of the public lands within said limits, for the purpose of ascertaining and demonstrating whether, as claimed, such lands or any of them are mineral in character, in that they

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[a] Meek, F. B. [Fourth Ann.], Preliminary Rept. U. S. Geol. Survey of Wyoming, 1871, p. 306.

[b] Emmons, S. F., Rept. U. S. Geol. Explor. 40th Par., vol. 2, 1877, p. 252.

[c] Ricketts, Louis D., Ann. Rept. Territorial Geologist of Wyoming for 1887, 1888, pp. 23, 42.

[d] Lander, F. W., Preliminary Report upon Explorations west of South Pass for a suitable location for the Fort Kearney, South Pass, and Honey Lake wagon route, 35th Cong., 2d sess., Senate Ex. Doc., vol. 10, No. 36, 1859, p. 33.

[e] Min. Res. U. S. for 1885, 1886, p. 154.

[f] Slosson, E. E., School of Mines, Univ. of Wyo., Petroleum ser., Bull. No. 3, 1899, p. 31.

[g] Decisions of the Department of the Interior and General Land Office in Cases relating to Public Lands, vol. 33, 1903, p. 50.

> are chiefly valuable for their oil or other mineral deposits; but in justice to the railroad company, whose line of railroad has long since been completed in conformity with the land-grant act, and in justice to others who may desire to take any of the public lands within said limits under any of the public-land laws other than the mining laws, it is necessary that this order of suspension shall not be operative longer than until December 1, 1903, that being deemed ample time within which, in addition to the exploration and exploitation heretofore had, to fairly develop the character of these lands.

The effect of this order was, on the one hand, to stimulate prospectors to attempt to develop this field, and, on the other, it is claimed, to make the Union Pacific Railroad hinder the development in such way as it might, being the one line of transportation in this region. Certain cases affecting sec. 23, T. 15 N., R. 118 W., and sec. 33, T. 14 N., R. 119 W., were heard before a special examiner in the district land office August 23 and 25, 1904, and the decision rendered that these tracts were not "known mineral lands," and that patent should be issued to the Union Pacific Railroad in accordance with the terms of its land grant. With the termination of this land contest, it is asserted, the railroad has offered freight facilities which will materially aid in the development of the field. The following table gives the wells drilled in this field up to the present time:

List of test wells for oil in southern Uinta County, Wyo.

Location.	Township.	Range.	Section.	Name of well or owner.	Year drilled.	Total depth in feet.[a]	Product.[b]	Remarks.
Hilliard (2 miles west)	13	119	4, NE. ¼ NE. ¼	Brigham Young oil spring or well.	1848 ?	57	W, O	Shallow well reported to have been sunk by order of Brigham Young on site of oil spring. Yields a few gallons per day.
Do	13	119	4, NW. ¼ NW. ¼	El Rio Verde Oil Co.	1902	1,600	W	Sunk near Brigham Young oil spring. This well is located on upper flank of an overturned syncline, and strata at bottom of well are higher geologically than those near surface.
			4, NW. ¼ NW. ¼	J. R. White	1902	100	W, O	Between El Rio Verde well and Brigham Young spring. Small amount of oil.
Hilliard (2 miles northwest)	14	119	33, SE. ¼ NW. ¼	Judge White oil spring.	1867	10±	W, O	Shallow pits in which oil collected and was skimmed from time to time from surface of water.
Do	14	119	33, SE. ¼ NW. ¼	Judge White well	1867–1868	480	W	Seepage of oil. Ricketts gives depth of this well as 250 feet and date 1869.
Do	14	119	35, SE. ¼ NW. ¼	Evanston Oil Co	1884	484	W	
Do	14	119	33, SE. ¼ NW. ¼	Consolidated Oil Co.	1902–1903	80	W	Seepage of oil.
Knight (3 miles west)	14	120	12, NW. ¼ SW. ¼	Betty's Oil and Development Co.	1902–1904	1,200	W	Flowing fresh water of good quality at 700, 1,020, and 1,197 feet. Flows 30 gallons per minute. Well in synclinal basin and entirely in the Eocene. (Pl. XII A.)
Altamont				Aspen tunnel (Union Pacific Railroad Co).	1900–1902		W, O	Considerable quantities of water and seepage of oil 1,600 feet from west end of tunnel. Oil represents seepage from Oil-spring fault.
Altamont (1 mile east)	14	118	18, NE. ¼ NW. ¼	Consolidated Oil Co.	1902	500		Well too shallow to reach oil-bearing shales in the Benton formation. Large amount of water reported near surface.
Spring Valley (2 miles south)	14	118	10, NW. ¼ NE. ¼	Pittsburg-Salt Lake Oil Co.	1902–1903	1,283	O	Large quantities of water are reported in this well at 805 feet. Oil was found at 862 and 1,005 in sand beds in a gray shale. The oil is heavy and black and quite different from that in the Benton shales. The well starts below the Benton oil shales, and the oil-bearing strata are Jurassic.
Spring Valley (1½ miles southwest.	14	118	4, NE. ¼ NE. ¼	Piedmont Oil Co.	1902–1903	500	W	Small quantities of water. Well not deep enough to reach oil-bearing shales.
Spring Valley (3 miles west)	15	118	31, SW. ¼ NE. ¼	Carter oil spring	1868		O	Shaft and shallow pits reported to have been dug here yielded 8 to 10 gallons of heavy black oil per day. Gravity 21.5° Baumé (Slosson).

[a] Approximate.

[b] W=water; O=oil; G=gas.

List of test wells for oil in southern Uinta County, Wyo.—Continued.

Location.	Township.	Range.	Section.	Name of well or owner.	Year drilled.	Total depth in feet.	Product.	Remarks.
Spring Valley (3 miles north)	15	118	31, SW. ¼ NE. ¼	Carter oil well	1886	225 228 300	O O	Estimated that 6 bbls. per day of heavy lubricating oil was obtained from wells Nos. 1 and 2.
Spring Valley (2 miles west).	15	118	32, NE. ¼ SE. ¼	Baker Bros.	1901–1902	1,400	W	Not deep enough to reach oil-bearing Benton shales. Strong flow of water caused well to be abandoned.
Spring Valley	15	118	34, NE. ¼	Consolidated Oil Co.	1902–1903	500 500 1,000	....	Reported as dry holes. All these wells reach the Benton shale.
....	....	....	34, E. ½ NW. ¼	Craig well	1902	2,000	O	Some oil between 1,000 and 1,100 feet. No water.
Spring Valley	15	118	27, SE. ¼ SE. ¼	Union Pacific Railroad Co.	1900–1901	1,183.5	O, W	Oil at 424–463, 567–575, 1,147–1,159 feet. Well is now flowing brackish water with a little oil. The water is reported to be from a depth of between 300 and 400 feet. Upper oil is amber in color, while lower is green. Gravity, 41–43° Baumé.
Spring Valley (½ mile northeast).	15	118	26, SE. ¼ NW. ¼	Illuminating Oil Co.	1902	800	....	"No oil." This well begins near base of the Benton oil-bearing shales.
Spring Valley (1 mile north).	15	118	26, NW. corner	Pittsburg-Salt Lake Oil Co.[a]	1903	1,530	O	Slight amount of oil at 835–845 feet. At 1,225–1,250 feet main oil sand. Some oil between 1,400 and 1,500 feet. Oil in Benton shales.
Do.	15	118	22, SE. corner	do.[a]	1902	1,388	O	Surface water. Oil sands at 1,025, 1,160, and 1,363 feet, in Benton shales.
					1903	1,726	O	Surface water. Oil sands at 780 (trace), 1,375, and 1,650 feet, in Benton shales.
					1903	2,065	....	Surface water. Slight showing of oil at 1,035, 1,270, and 1,675 feet.
					1903, 1905	1,400	O	
Spring Valley (2 miles northwest).	15	118	22, NW. ¼ NW. ¼	Nebergall well	1901	1,600	....	No oil. This well was not deep enough to reach the oil-bearing Benton shales.
Spring Valley (1 mile north).	15	118	23, SW. corner	Consolidated Oil Co.	1903	1,115+	O	Oil at 800–820 (trace) and 1,100 feet, in Benton shales.
Spring Valley (2 miles north)	15	118	23, SE. ¼ NW. ¼	do.	1903–1904	1,100+	O	Oil at 600 (trace), 800, and 1,000–1,100 feet.

[a] To Messrs. A. V. Taylor and D. H. McMillan of this company we are indebted for this as well as other important information.

List of test wells for oil in southern Uinta County, Wyo.—Continued.

Location.	Township.	Range.	Section.	Name of well or owner.	Year drilled.	Total depth in feet.	Product.	Remarks.
Spring Valley (2½ miles north).	15	118	14, SW. ¼	Consolidated Oil Co	1902	1,140	W	This well was used to supply water for drilling adjoining wells, being the only well which yielded enough water for this purpose. The water is reported to be from a depth of about 300 feet.
Spring Valley (2½ miles northeast).	15	118	14, SE. ¼	do	1902–1903	1,000 950 1,030+	 O O	Dry hole. Reported to be best oil well in field.
Spring Valley (3 miles northeast).	15	118	14, NE. ¼	do	1902	1,190	O	Surface water.
Spring Valley (2½ miles north).	15	118	15, NE. ¼ SW. ¼	do		500		Entirely in Wasatch beds.
Spring Valley (3½ miles northeast).	15	118	12, SW. corner	Jaeger Oil Co	1902	1,250	O	Oil reported at 950 feet; water reported at 1,250 feet.
Spring Valley (4 miles northeast).	15	118	12, SE. ¼ NW. ¼	Standard Reserve Oil Co.[a]	1904	1,235	O	Oil reported at 90–120, 195–220, 560–655, 888–915, and 1,232–1,235 feet. The last is in the Bear River formation; the others in the Benton shales.
Bridger Station	16	117	2, NE. ¼ SW. ¼	Union Pacific Railroad Co	1893 ?	1,385	W, G	Impotable water.
Evanston (11 miles north)	17	120	26, SE. ¼ SW. ¼	Michigan-Wyoming Oil Co.	1903	1,238		No oil. Well starts near base of Bear River formation on north slope of a faulted, steeply pitching anticline.
Round Mountain	17	118	14, SE. corner	Intermountain Oil Co.	1901–1902	600		No oil. Well drilled on upper flank of overturned syncline. Strata at bottom of well are higher geologically than those at the top.
Fossil (1 mile west)	21	117	7, NW. ¼ NW. ¼	Idaho-Wyoming Oil Co.	1901–1902	1,710	W	Impotable water between 800 and 1,000 feet; flows 5 gallons per minute. Well in synclinal trough deeply filled with Eocene between Absaroka fault uplift and Rock Creek anticline.
Fossil (3 miles east)	21	117	11, SE. ¼ SW. ¼	Robinson well	1895 ?	100±		Well located near small anticline in Wasatch beds, produced by slight movement of underlying buried Absaroka fault.
Fossil (3½ miles southeast)	21	117	14, NW. ¼	Seitz well	1902	15	O	Small quantity of oil. Open well dug near oil spring.

[a] To the manager of the above company, Mr. Charles O. Richardson, a civil and mining engineer, we are indebted for the above information and for one of the most complete oil-well records obtained in this field. This record will be published in the complete report now in preparation.

List of test wells for oil in southern Uinta County, Wyo.—Continued.

Location,	Township.	Range.	Section.	Name of well or owner.	Year drilled.	Total depth in feet.	Product.	Remarks.
Fossil (4 miles southeast)...	21	117	23, NE. ¼ NE. ¼....	Fossil Consolidated Oil Co.	1902	750	W, O	Oil reported at 520 feet.
Do........................	21	117	23, SW. ¼ NE. ¼ ...	Twin Creek Land and Oil Co.	1885	100	W, O, G	Flowing brackish sulphur water with a little oil and gas. Well caved.
				Twin Creek Land and Oil Co. (Clark well).	1887	185	W, O, G	Flowing brackish sulphur water with a little oil and gas. Well still open.
Fossil (4½ miles southeast)...	21	117	27, NE. ¼ SE. ¼....	Utah-Wyoming Oil Co.	1902–1903	1,110	W, G	Flowing brackish sulphur water with some gas.
Fossil (5 miles southeast)...	21	117	26, SW. ¼ SE. ¼....	Globe Oil Co.........	1903–1904	600	W, G, O	Flowing brackish sulphur water with some gas and a trace o oil. Well located in small syncline in Wasatch beds, produced by movement along Absaroka fault.
Do........................	21	117	26, SW. ¼ SE. ¼....	Paraffine Oil Co......	1902–1903	147	W, O	Two wells. Flowing brackish sulphur water with a little oil.
Fossil (6 miles southeast)...	21	117	25, SE. corner.....	Orlando Curtis.......	1903	457	....	Drilled entirely in Laramie Cretaceous beds.
Fossil (7 miles southeast)...	20	117	6, SW. ¼ SW. ¼	G. Short..............	1903–1904	2,200	....	Red beds from 1,650 to 2,200 feet. These are probably highly inclined upper Jurassic (?) beds on the west side of Absaroka fault. (Pl. XII, B.)

GEOLOGIC RELATIONS.

The natural oil springs in this area occur in the region of profound disturbance along the Absaroka fault (Pls. XI, XII).

The Brigham Young, White, and Carter springs occur along a secondary fault just east of the main fault line. This secondary fault cuts the west end of the Aspen tunnel, and the oil seepage reported in this tunnel is to be regarded as essentially of the same character as that in the neighboring oil springs. In these cases the oil issues directly from faulted Cretaceous rocks, of Benton age, at a horizon stratigraphically 1,600 feet above the top of the black shales, which yield oil in the wells at Spring Valley. As these lower shales are about 1,000 feet thick, it would require a hole 2,600 feet deep at the fault line to prospect them fully if the strata were horizontal, but as they are highly inclined, wells drilled at the fault line must go to much greater depths. Where, as at Hilliard, the strata are overturned, a well at the fault line, like the El Rio Verde well, must drill through some of the strata twice, and such a location is to be avoided both because of the unnecessary duplication required and because the oil yield will be smaller than at greater distances from the fault, owing to loss by leakage along the fault line.

In the vicinity of Fossil the oil comes from a group of springs which, with the exception of occasional globules of oil, are of the type commonly found in the Eocene beds. The strata around these springs and for many feet below belong to the Wasatch. These beds show a gentle anticline with dips of about 5°, and the springs occur very near the axis. To the east, between this anticline and the outcrop of the coal-bearing Laramie beds, is a similar syncline. The geologic relations of the adjoining areas indicate conclusively that the position and direction of this anticline corresponds very nearly with those of the underlying Absaroka fault, and that it has doubtless been produced by a slight movement along this older axis (Pl. XII, *B*). The oil floating up through the water which has penetrated to the oil-bearing beds along the fault has naturally, in the fairly water-logged beds of the Wasatch, collected and found outlet along this low anticline, which is at the same time the highest point stratigraphically and the lowest point topographically, and is almost directly over the fault line. The Short Well penetrated red beds from 1,650 feet to the bottom of the well—2,200 feet—conclusively showing that it is situated west of the Absaroka fault. The other wells in this field obtained water, with a little gas and oil, in the Wasatch beds. The conditions here are manifestly unfavorable for the accumulation of oil in commercial quantities.

At Spring Valley in all wells except the one in sec. 10, T. 14 N., R. 118 W., which will be discussed later, oil is found in sandy layers in a black shale. Geologically this black shale occurs in the basal portion of the Benton. Failure to obtain oil has been recorded in three types of wells: (1) Those not deep enough to reach the oil-bearing strata, such as the Nebergall and Baker wells (Pl. XII, *B*); (2) those which, because of irregularities of the sandy layers in the shales, fail to develop oil, although it is found in adjacent wells (examples of this type are the Consolidated Oil Company's wells in the southwest corner of sec. 23, T. 15 N., R. 118 W.); (3) those located on the outcrop of the shales, particularly those near the eastern edge, where the beds are less than 500 feet thick—such as the well of the Illuminating Oil Company in sec. 26 and the well on the west side of sec. 24, T. 15 N., R. 118 W.

In general, no oil is found along the outcrop of this bed, but the amount increases with the dip. This, together with the irregularity shown in the position of the oil-bearing sands in adjoining wells and the fact that no water has been found in the oil-bearing beds,[a] suggests that this oil has been formed from the shale in which it is found, and that the oil-bearing sands represent local sandy layers more or less perfectly surrounded by shales in which the oil has accumulated. This is the case also in the Boulder and Florence fields, although at those localities the shales are geologically younger. Where water is absent from the oil-bearing beds oil tends to move down the dip, and so far as the continuity of the porous beds allows will collect in the troughs of the synclines. This is apparently the case in this field, and the position of the syncline and the depth of the oil-bearing shale at its lowest point thus becomes one of considerable economic importance. At Hilliard the lowest point in the shale bed is over 11,000 feet from the surface and the dip of the beds is such that a deep well would be extremely difficult to sink. Between Hilliard and the Aspen tunnel the syncline rises and these beds may be thoroughly prospected with a hole 2,500 to 3,000 feet deep. This is a good location, although the oil-spring fault to the west introduces a point of leakage and the deepening of the syncline to the south affords a lower point of accumulation. Because of the normal character of the syncline at this point, a well properly placed may be drilled entirely in nearly horizontal strata.

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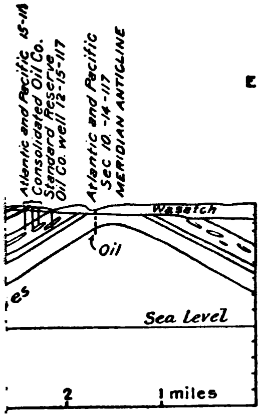
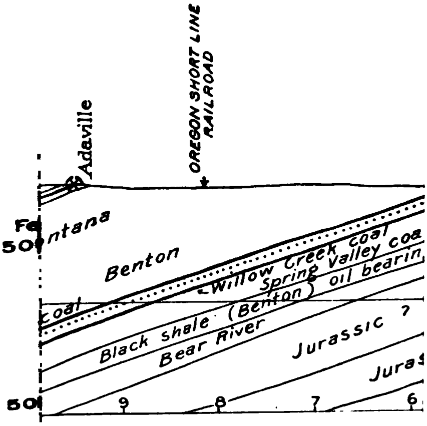
[a] While water has been encountered in several wells in the Spring Valley region, in no case is it associated with the oil-bearing strata, and when the oil is pumped out no water follows. Water occurs more or less abundantly in the Tertiary beds, as shown by the artesian wells in the vicinity of Fossil and the Bettys well between Hilliard and Evanston. Where wells are started in the Cretaceous, water is sometimes found in the upper part of the well, but the oil-bearing beds are dry. There are several conflicting reports of water encountered below the oil-bearing beds, but in these cases, assuming that water really was struck where reported, there seems to be no reason for believing that it is in any way associated with the oil.

Northward the synclinal trough deepens rapidly, and at the Lazeart mine the oil shale is perhaps 10,000 feet from the surface. At Round Mountain the strata are overturned and faulted and the site is not favorable for an oil well. Between Round Mountain and the top of the Adaville beds, north of Little Muddy Creek, the synclinal trough rises. The rise is gradual, the syncline is normal, and the locality in these respects is the best in the region. However, the great depth of the oil-bearing shales—5,000 to 7,000 feet—is practically prohibitive. To the north the syncline sinks, and at the Oregon Short Line the lowest point of the oil-bearing beds is about 15,000 feet from the surface. Farther north the syncline rises, and in the long trough north of a point 10 to 15 miles north of Kemmerer the conditions are very favorable. The depth of the oil-bearing shale in the center of the syncline is such that wells could be readily sunk, and test holes here are likely to yield returns. This region is beyond that examined this year, but enough was learned regarding it to warrant the above suggestion. Moreover, oil springs are reported in this region, and it is hoped that they may be critically examined next year.

In general, in the region covered by this report the depth of the oil-bearing shales at the axis of the syncline is practically prohibitive, but the soft character of the strata suggests that the diminution of pore space, due to the pressure of the superincumbent beds, may be so great that the maximum accumulation of oil will be at some point on the limb of the syncline, between the axis and the outcrop. Indeed, though the oil-bearing shales underlie a much larger area, prospecting should be restricted to the region between the axis of the Lazeart syncline and the eroded edge of the bed on the west flank of the Meridian anticline (Pl. XI).

The well of the Pittsburg and Salt Lake Oil Company, in sec. 10, T. 14 N., R. 118 W., develops an entirely different horizon. It is so situated that after passing through the Wasatch beds it strikes the older rock below the oil-bearing Benton shale (Pl. XII, *A*). It develops two oil-bearing sand beds in a light-blue shale, which is probably Jurassic and of the same age as the shale exposed on Twin Creek west of Nugget. The oil is black and more in the nature of a lubricating oil than that from the upper horizon. Prospecting for these lower horizons may well be carried on near and just west of the Meridian anticline. If in these lower strata water is also absent, the greatest yield will be found down the dip. In attempting to develop the shales of the same age on Twin Creek test wells should be located west of the outcrop and in such a position that 500 or 1,000 feet of red beds may be drilled through before reaching the shales.


Atlantic and Pacific 15-118
Consolidated Oil Co.
Standard Reserve Oil Co. well 12-15-117
Atlantic and Pacific Sec 10.-14-117
MERIDIAN ANTICLINE
E
Wasatch
Oil
es
Sea Level
2
1 miles



beds above Absaroka fault.

QUALITY OF OIL.

The oil obtained from the Brigham Young, White, Carter, and Fossil oil springs, and wells in their neighborhood, is a dark, heavy oil which has perhaps been derived in part from the Benton oil by the evaporation of its more volatile portions. The gravity of the Carter oil is given by Slosson [a] as 21.5° Baumé. The gravity of the Fossil or Twin Creek oil is given by the Union Pacific Railroad [b] as 26.75° Baumé and by Slosson [a] as 19.7° Baumé. The results of several analyses of the Spring Valley petroleum are given below:

Analysis of oil from Union Pacific well at Spring Valley, Wyo.

[By Thomas Price & Son, San Francisco, 1901.]

	Per cent.
Naphtha (gasoline and benzine)	28
Kerosene	24
Signal and headlight oil	8
Lubricating, reduced stock	23
Paraffin	17

Analysis of oil from 650-foot sand of Union Pacific well at Spring Valley, Wyo.

[By Louis Falkenau, San Francisco, 1901.]

	Per cent by volume.	Per cent by weight.	Specific gravity.	Gravity Baumé.	Nature of product.
Given off at—				°	
66°-302° F.	15.0	17.1	0.740	60	Gasoline and benzine.
302°-491° F.	33.1	33.4	.802	46	Illuminating.
491°-602° F.	26.5	27.1	.830	35	Heavy illuminating or signal.
602° F. (boiled dry)	19.5	20.4	.840	31	Lubricating and paraffin.
Residue:					
Bituminous (soluble)		1.0			
Carbon and ash (insoluble)		1.0			

Specific gravity of crude at 66° F., 0.825.
Crude flashes at 66° F.

Analysis of oil from Union Pacific well, Spring Valley, Wyo.

[By G. W. Gray, chemist, Standard Oil Company, 1902.]

	Per cent.
Gasoline	19
Refined illuminating oil	35
Heavy lubricating oil	21
Intermediate lubricating oil	21
Coke	1.8
Loss	2

Sample baled from well upon first day of opening, Thursday, January 26, 1902, run into tank car, and taken from tank car Sunday, June 29, 1902.

Gravity, 0.8211, or 41.5° Baumé.

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[a] Slosson, E. E., Bull. School of Mines, Univ. Wyoming, petroleum series, No. 3, 1899, p. 31.
[b] Mineral Resources U. S. for 1885, U. S. Geol. Survey, 1886, p. 154.

Analysis of oil from Union Pacific well, Spring Valley, Wyo.

[By Wilbur C. Knight, professor of geology, University of Wyoming, 1902.]

No.	Temperature given off.	Specific gravity.	Remarks.
1	77°-130° C	0.7230	Oil at 15° C.
2	130°-170° C	.7540	Do.
3	170°-200° C	.7800	Do.
4	200°-259° C	.8040	Do.
5	259°-292° C	.8190	Do.
6	292°-320° C	.8340	Do.
7	320°-350° C	.8470	Oil at 18° C.
8	350°-370° C	.8580	Oil at 22° C.
9	370°-380° C	.8640	Do.
10	380°-400° C	.8880	Do.

Specific gravity of crude oil, 0.81.

Oil flashes at a point below 70° F.

The above numbers represent tenths of the product, with the exception of the last, which was only half filled This means that with the ordinary method of distilling oils 95 per cent of the crude would be saved.

This oil will yield approximately, the following products: Gasoline and lighter oils, 20 to 30 per cent; kerosene, 30 to 40 per cent; paraffin, 10 to 20 per cent. The remainder of the oil could be utilized to some extent for lubricating purposes.

This is a superior quality of crude for the production of gasoline and kerosene, but of little importance for lubricants For the lighter oils it is worth a little more than the ordinary crude from Colorado or Pennsylvania.

Analysis of oil from well of Pittsburg-Salt Lake Oil Company in sec. 22, T. 15 N., R. 118 W., 1 mile north of Spring Valley, Wyo.

[By C. F. Mabery, Cleveland, Ohio, 1906.]

	Per cent.	Gravity Baumé.	Nature of product.
Given off at—		°	
50°-150°	21.3	65	Gasoline.
150°-305°	39.7	44	Burning oil.
305°-350°	16.4	36	Gas oil.
350°-330°	15.4	37	Cracked oil (partially cracked).
Residue	7.2		

Specific gravity, 0.81, or 44° Baumé.

The oil begins to crack at 350°; of course this product is really gas oil. The distillates 305°-350°, 350°-330°, and the residue contain much paraffin. These oils become solid when cooled in tap water with paraffin, so the yield is large.

We refined some of the burning oil; not, however, with reference to flash nor complete absence of color. It refines very easily and gives a very fine grade of burning oil.

Of course, the proportions of products will be somewhat different on a refining scale (1,000 barrels)—probably larger, rather than smaller, than is given on the small scale.

This petroleum is different from any of the numerous specimens that I have previously examined from the Wyoming territory.

A large amount of very light gasoline can be separated by strong cooling.

With respect to the large proportion of gasoline and of burning oil, also of paraffin, this petroleum is one of the most valuable that I have ever examined.

It is a nonsulphur oil; percentage of sulphur, 0.03.

Very little lubricating oil can be obtained, and that only light, 28° to 30°, as the oil begins to crack at 350° or less and will not stand higher distillation for the manufacture of heavier oils.

The paraffin in this oil is 6.2 per cent of the weight of the crude oil—more than is usually found in American petroleum.

RÉSUMÉ OF OIL SITUATION, WITH SUGGESTIONS.

The best oil territory in this region is between the axis of the Lazeart syncline and the outcrop of the oil-bearing shales west of the Meridian anticline (Pl. XI). The oil-bearing horizon is low in the Benton, and the oil is of high grade, carrying a large percentage of illuminants and a paraffin base.

The whole territory underlain by the Benton shales may be expected to yield oil of the same character as that found at Spring Valley, and a considerable oil field is thus outlined. Present developments indicate that the quantity obtained will increase toward the axis of the Lazeart syncline.

A single well has shown the presence of lower oil horizons yielding heavy lubricating oil. These are probably Jurassic, and prospecting for them should first be carried on along the Meridian anticline. Success at this point would suggest that similar developments be undertaken west of Rock Creek.

In developing this section wells should preferably be placed in valleys, first, because such locations will save much needless drilling; second, because a water supply can often be obtained in shallow bored wells in such locations; and third, because supplies can be transmitted more cheaply.

Between the Absaroka fault and the Rock Creek-Needles anticlinal this principal oil-bearing horizon is in general either deeply buried or absent and is not of probable economic importance.

West of the Rock Creek-Needles anticlinal the rocks are all older than the Benton oil-bearing shales, with the exception of the Evanston and Tertiary beds, which are not oil bearing.

UNDERGROUND WATERS.

The coarse beds in the Wasatch have yielded flowing water in several wells near Fossil and in Betty's well between Evanston and Hilliard. The Wasatch beds here have been tilted into a gentle syncline by movements along the Absaroka fault and the Rock Creek-Needles anticlinal. In all deep valleys between these two structural features similar flowing wells are to be expected (Pl. XI). At Fossil the water is brackish and of no evident economic importance. At Betty's well, however, it is reported of good quality, and similar flowing water may confidently be expected throughout that portion of Bear River Valley and in Needle, Goodwin, and Yellow creeks. In the bottoms along Bear River it will develop a very considerable head.

SURVEY PUBLICATIONS ON COAL, LIGNITE, AND PEAT.[a]

The more important United States Geological Survey publications on coal, lignite, and peat are listed below. Those immediately following deal with coal:

Arnold, R. Coal in Clallam County, Wash. In Bulletin No. 260, pp. 413–421. 1905.

Ashley, G. H. The eastern interior coal field. In Twenty-second Ann. Rept., pt. 3, pp. 265–305. 1902.

——— The Cumberland Gap coal field of Kentucky and Tennessee. In Bulletin No. 225, pp. 259–275. 1904.

——— Coal in the Nicholas quadrangle, West Virginia. In Bulletin No. 260, pp. 422–428. 1905.

——— and Glenn, L. C. Geology and mineral resources of part of the Cumberland Gap coal field, Kentucky. In Professional Paper No. 49, pp. 1–225, 1906.

Bain, H. F. The western interior coal field [Iowa, Missouri, and Kansas]. In Twenty-second Ann. Rept., pt. 3, pp. 333–366. 1902.

Branner, J. C. The coal fields of Arkansas. In Mineral Resources U. S. for 1892, pp. 303–306. 1893.

Burrows, J. S. The Barnesboro-Patton coal field of central Pennsylvania. In Bulletin No. 225, pp. 295–310. 1904.

Butts, C. Coal mining along the southeastern margin of the Wilmore basin, Pennsylvania. In Bulletin No. 225, pp. 325–329. 1904.

——— The Warrior coal basin in the Brookwood quadrangle, Alabama. In Bulletin No. 260, pp. 357–381. 1905.

Campbell, M. R. Geology of the Big Stone Gap coal field of Virginia and Kentucky. In Bulletin No. 111, pp. 13–106. 1893.

——— Recent work in the bituminous coal field of Pennsylvania. In Bulletin No. 213, pp. 270–275. 1903.

——— The Deer Creek coal field, Arizona. In Bulletin No. 225, pp. 240–258. 1904.

——— The Meadow Branch coal field of West Virginia. In Bulletin No. 225, pp. 330–344. 1904.

Campbell, M. R., and Haseltine, R. M. The northern Appalachian coal field. In Twenty-second Ann. Rept., pt. 3, pp. 119–226. 1902.

Campbell, M. R., and Mendenhall. W. C. Geologic section along the New and Kanawha rivers in West Virginia. In Seventeenth Ann. Rept., pt. 2, pp. 473–511. 1896.

Chance, H. M., Anthracite coal mining. In Mineral Resources U. S. for 1883 and 1884, pp. 104–143, 1885.

Darton, N. H. Coal of the Black Hills, Wyoming. In Bulletin No. 260, pp. 429–433. 1905.

Day, W. C. The coal and pitch coal of the Newport mine, Oregon. In Nineteenth Ann. Rept., pt. 3, pp. 370–376. 1899.

Diller, J. S. Coal in Washington, near Portland, Oreg. In Bulletin No. 260, pp. 411–412. 1905.

——— The Coos Bay coal field, Oregon. In Nineteenth Ann. Rept., pt. 3, pp. 309–376. 1899.

Fisher, C. A. Coal fields of the White Mountain region, New Mexico. In Bulletin No. 225, pp. 293–294. 1904.

——— Coal of the Bighorn Basin in northwest Wyoming. In Bulletin No. 225, pp. 345–362. 1904.

Forrester, R. Coal fields of Utah. In Mineral Resources U. S. for 1892, pp. 511–520. 1893.

Fuller, M. L., and Ashley, G. H. Recent work in the coal field of Indiana and Illinois. In Bulletin No. 213, pp. 284–293. 1903.

Griswold, W. T. Pittsburg coal in the Burgettstown quadrangle. In Bulletin No. 260, pp. 402–410. 1905.

Haseltine, R. M. The bituminous coal field of Ohio. In Twenty-second Ann. Rept., pt. 3, pp. 215–226. 1902.

Hayes, C. W. The coal fields of the United States. In Twenty-second Ann. Rept., pt. 3, pp. 7–24. 1902.

——— The southern Appalachian coal field. In Twenty-second Ann. Rept., pt. 3, pp. 227–263. 1902.

——— Coal fields of the United States. In Bulletin No. 213, pp. 257–269. 1903.

Hills, R. C. Coal fields of Colorado. In Mineral Resources U. S. for 1892, pp. 319–365. 1893.

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[a] This bibliography was prepared by Mr. W. C. Phalen.

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Knight, W. C. Coals and coal measures of Wyoming. In Sixteenth Ann. Rept., pt. 4, pp. 208-215. 1895.

Lane, A. C. The Northern interior coal field. In Twenty-second Ann. Rept., pt. 3, pp. 307-331. 1902.

McCreath, A. S., and **D'Invilliers**, E. V. The Clinch Valley coal field. In Mineral Resources U. S. for 1892, pp. 521-528. 1893.

Parker, E. W. Coal. In Mineral Resources U. S. for 1894, pp. 1-217. 1896.

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Safford, J. M. The Tennessee coal measures. In Mineral Resources U. S. for 1892, pp. 497-506. 1893.

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PETROLEUM AND NATURAL GAS.

THE SALT LAKE OIL FIELD NEAR LOS ANGELES, CAL.

By Ralph Arnold.

Introduction.—Since the completion, four years ago, of the examination of the California oil districts by the late G. H. Eldridge, one of the most important fields in the State has been developed near the city of Los Angeles. This field, locally known as the Salt Lake from its first important producing company, has grown from a position of comparative insignificance in 1902 to that of possibly the premier field of southern California in 1905.

Location and topography.—The Salt Lake oil field occupies an area approximately a mile square, 7 miles west of the business portion of Los Angeles, Cal. (see fig. 12). The field is a part of the Los Angeles-Santa Monica plain, which extends southward with a gradually lessening slope from the base of the Santa Monica Range toward the hills southwest of Los Angeles. With the exception of a few unimportant ravines which run in a general southwesterly direction across the plain and an extensive slope which descends gradually from the field northwestward toward Sherman, there is little to break the topographic monotony in the vicinity of the wells. A small artificial lagoon, made by the removal of large quantities of brea, occupies a depression about 75 by 150 yards near the center of the southern part of the field. Reference will be made to this lagoon later in the discussion.

Geologic formations.—Alluvium and Pleistocene deposits of gravel, sand, and clay cover the plain in the region of the Salt Lake field, but surface outcrops of other beds are to be found no nearer than about 2 miles from the present developed territory. The well logs and a study of the adjacent region indicate, however, that the formations involved in the geology of this field include at least a part of those exposed to the east, in the vicinity of the Los Angeles city field, and consist of (a) 2,000+ feet of lower Miocene sandstone, (b) 2,000± feet of middle and possibly upper Miocene shales and thin-bedded sandstones, (c) 2,000+ feet of Pliocene clayey and sandy shale, sandstone, and gravel, and (d) an unconformable capping of Pleistocene gravel, sand, and clay varying in thickness from 40 to at least 100 feet or more, the whole covered by alluvium.

The lower Miocene sandstones are coarse, arkose, and heavy bedded, gray to rusty brown in color, sometimes concretionary in structure, and often jointed. They are interbedded at irregular intervals by smaller amounts of dark-colored earthy and lighter siliceous shales. Toward the top of the series, however, the shales become relatively more abundant. No sharp line of demarcation separates the sandstones from the overlying series, which consists largely of shales of middle and possibly upper Miocene age. The lower 1,000 feet of this series are made up of hard, white, thinly laminated siliceous shale, occurring in bands 200 feet or less in thickness, alternating with thinner bands of sandstone similar to those of the lower Miocene. About 1,000 feet of soft, thin-bedded sandstone and sandy shale, with some hard siliceous members and coarser sandstone toward the top, overlie the white-shale beds. The upper portion of this upper shale series, and possibly some of the strata of the superjacent formation yield the oil, the most productive sands appearing to lie beneath the uppermost prominent band of hard siliceous shale. The oil is probably derived from the diatoms and other minute vegetable remains found in the underlying shale, and finds its way into the sandy layers at the top of the series mainly through the multitude of joint cracks which penetrate both the shale and sandstone. The Miocene shales are overlain (probably unconformably, although having the same general dip) by at least 2,000 feet of Pliocene sediments, which in the Salt Lake field appear to consist largely of clayey shale with occasional interbedded sandy or gravelly layers. The Pleistocene beds are made up of clay, sand, and gravel, the clay predominating, and are often highly impregnated with oil, forming brea.

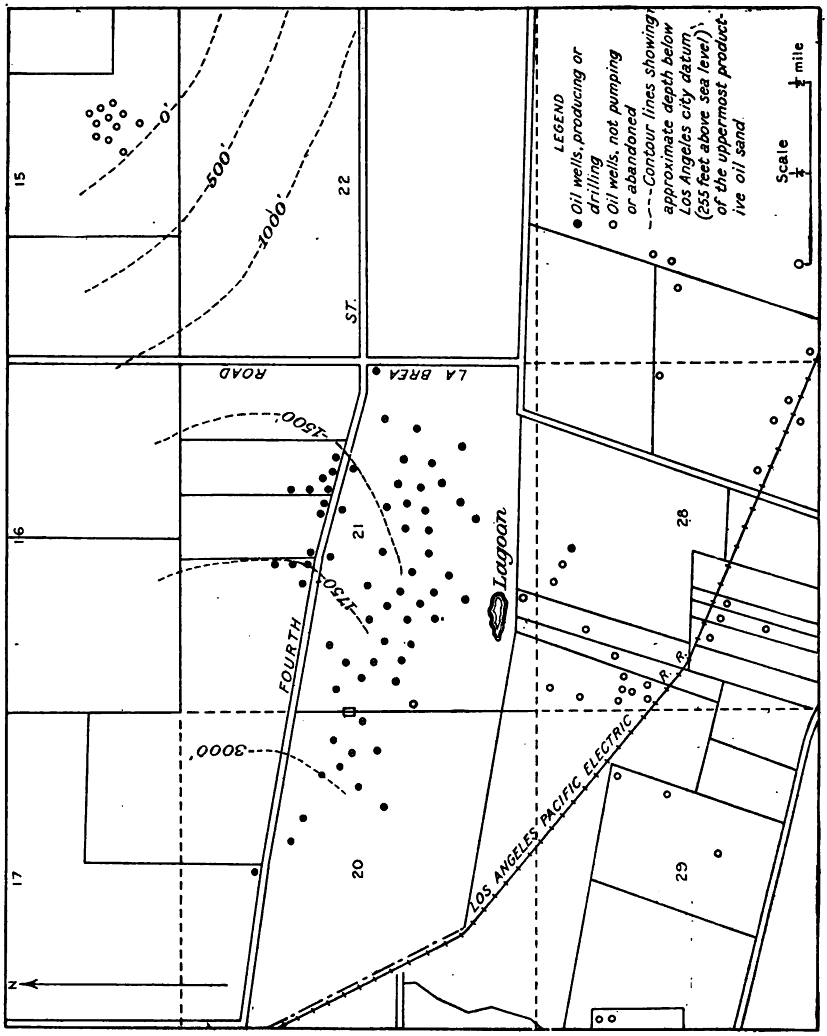
LEGEND
● Oil wells, producing or drilling
○ Oil wells, not pumping or abandoned
- - - Contour lines showing approximate depth below Los Angeles city datum (255 feet above sea level) of the uppermost productive oil sand.
Scale
0
¼ mile
T. 1 S. R. 14 W.
15
16
17
20
21
22
28
29
0'
500'
1000'
1500'
1750'
3000'
LA BREA ROAD
FOURTH ST.
Lagoon
LOS ANGELES PACIFIC ELECTRIC R.R.
N

FIG. 12.—Map of the Salt Lake oil field, 7 miles west of Los Angeles, Cal.

Great deposits of this brea occur in the immediate vicinity of the lagoon and north and northwest of it for a considerable distance. Numerous bones of extinct Pleistocene mammals, such as the saber-toothed tiger, elephant, giant sloth, cave bear, camel, and dog are embedded in this brea, and indicate not only the age of the deposits but also the important fact that the conditions favorable to the accumulation of the brea have been in existence here at least since the middle or latter part of the Pleistocene epoch. Heavy oil exudes from the banks of the lagoon and from some of the minor brea pits, while the constant escape of natural gas is evidenced by the continuous streams of bubbles which rise to the surface of the water in the different depressions.

Geology of the wells.—The wells usually penetrate, for the first 50 to 100 feet or more, alluvium and clay, with varying amounts of coarse sand and gravel, representing the Pleistocene covering of the older formations. These deposits carry water, which in some instances is mineralized, in one or more of the beds. A little heavy oil or asphaltum is also occasionally found in the superficial deposits. In fact, in some parts of the field the oil appears to impregnate the soil and rocks "from the grass roots down." From the Pleistocene to the first important oil sand (which is struck at from 1,000 to 3,000 feet) the beds consist of soft sandy shale ("adobe") and clayey shale, with occasional 1 to 6 foot layers of hard siliceous or calcareous shale ("shell") and sometimes a little sand and gravel. This series belongs in large part to the Pliocene. Oil and gas, increasing in quantity downward, are found in many of the beds of this series, the largest accumulations usually occurring just beneath the hard, impervious "shell" layers. Salt water is also encountered at various depths, the more aqueous horizons appearing at about 150 feet above and between 950 and 1,000 feet above the top of the uppermost productive sand. Another bed carrying salt water is encountered about 150 feet below the lowest important oil sand. This water attains a temperature of 110° in some of the wells. The oil zone proper varies in thickness from 150 to nearly 500 feet, and consists of alternating thick-bedded rather coarse sand and clayey shale and "shell." Whether or not the sand occurs as persistent layers, or rather as lenses, is problematical, although it is highly probably that it is present in both forms within the area under discussion. This much is known, however, that the uppermost important sand in the wells over a large part of the field appears to occupy the same horizon. The lower limit of the productive zone is usually a sterile white sand, sometimes locally hardened, which yields, at a depth of 150 feet or more below its top, large quantities of warm or hot salt water. One well, it is said, struck some 11° oil in this lowest salt-water stratum. A typical section through the oil zone, where the dip is approximately 15°, is as follows:

Typical section of oil-sand zone in Salt Lake field.

	Feet.
Sandy shale ("adobe")	300+
Oil sand	20
Clayey shale	30
Oil sand	10
Clayey shale	20
Oil sand	20
Hard shale	2
Oil sand	123
Tough brown shale	10
Oil sand	25
Clayey shale	10
Oil sand	10
Clayey shale	86
Oil sand	129
White sand	150
Sand with salt water (hot) and occasionally some 11° oil	200+
Total productive sand	337

Structure.—Owing to the almost complete absence of surface evidence in the immediate vicinity, the determination of the local structure of the Salt Lake field rests largely on the interpretation of the well logs. All of these, unfortunately, were not available at the time of the writer's visit to the field, so that the conclusions reached, although probably correct in the main, lack that detail and definiteness which is so desirable in an economic report of this sort.

The strictly local structure of the field under discussion will be more fully comprehended if its description is prefaced by a word in regard to the general structure of the Los Angeles district as a whole. Practically all the productive oil sands of the different Los Angeles fields lie on the south limb of a flexure, usually a more or less well-defined anticline, whose axis extends in a westerly direction from the vicinity of the Catholic cemetery on Buena Vista street to the region approximately half a mile north of Westlake Park, where it bends about 20° north and extends to a point about three-fourths of a mile southeast of Colegrove and something over a mile northeast of the Salt Lake field. Here it appears to bend to the north again, probably trending about N. 60° W. In the Los Angeles city field—that is, between the Catholic cemetery and the Westlake Park region—the south limb of the flexure dips normally at angles varying from 30° to 80°, while to the west, along that portion having a northwesterly trend, the dips flatten to 20° or 25°. The Salt Lake oil field is located on the northwestern flank of a minor but probably somewhat complex fold or flexure developed on the comparatively low-dipping southwest limb of the major flexure just described.

The exact nature of the local flexure is not known, but it is probably an anticline, possibly complicated by faulting, with its axis extending in a general northeast-southwest direction. The available evidence appears to indicate that the flexure extends from near the center of the SE. ¼ sec. 15, T. 1 S., R. 14 W., at least as far as the lagoon in the SW. ¼ sec. 21, but whether or not it continues farther to the southwest is problematical. The large accumulations of brea in the immediate vicinity of the lagoon and to the north and northwest of it, in addition to the constantly exuding oil and escaping gas over the same area, indicate some sort of a profound local disturbance or fracture in the underlying beds. If this disturbance has an extensive longitudinal dimension in a northwesterly direction from the lagoon, as some of the evidence appears to suggest, then it is possible that this northwesterly trending disturbance may cut off the Salt Lake flexure from a southwesterly extension beyond the lagoon. If, however, the disturbance in the vicinity of the lagoon is of the nature of a local bulge or dome in the underlying beds, it is very likely that the Salt Lake flexure may have a considerable southwestern prolongation.

The map (fig. 12, p. 358), on which the dotted contour lines show the probable distance of the top of the uppermost important oil sand below the Los Angeles city datum (255 feet above sea level), illustrates the writer's ideas concerning the structure of the northwest limb of the Salt Lake flexure. From this it will be seen that the strike of the oil sand swings around from a nearly east-west line in the region north of the lagoon to a direction slightly west of north in the NE. ¼ sec. 21. The dip of the sand in the region about the center of sec. 21 does not appear to be much more than 10° or 15°, but it increases rapidly in steepness both southeast up and northwest down the dip. The region immediately southeast of the Salt Lake flexure, although supporting some small producing wells—one of which attains a depth of nearly 3,000 feet—does not compare in productiveness with the territory to the northwest. This condition may be explained on several hypotheses, the two most probable being either (*a*) that the Salt Lake flexure is accompanied by faulting which has dropped the productive sands on the southeast down out of reach of the drill or raised them up to such an elevation that they were eroded away in a period subsequent to the faulting, or (*b*) that the continuation of the productive beds passes over the flexure (in this case an anticline) and down on the southeastern flank, but under conditions unsuited to the accumulation of the oil in the large quantities encountered on the northwestern limb.

Suggestions for future development.—Anyone at all familiar with the conditions of occurrence of petroleum in the California fields knows that any but the most tentative predictions as to the location of the oil are extremely hazardous. The following suggestions, based on the evidence in hand, although lacking definiteness for the reasons above stated, may be of some assistance to those engaged in developing this field.

It seems probable that the productive zone of the Salt Lake field extends northward, and possibly a little westward, from the territory now developed. Just where the northern limit is located is problematical, but it is quite certain that it is considerably south of the base of the Santa Monica Range. Within this northern extension the beds in general dip to the west, and for this reason the most productive area will doubtless be found west of La Brea road. East of this road the oil sands approach the surface and consequently yield smaller quantities and heavier oil than do the same beds farther down the dip. As shown by several wells drilled in the region southeast of the Salt Lake flexure, this territory does not appear to offer many inducements for exploitation, at least in the immediate vicinity of the Salt Lake field. Farther east, however, in the region west and southwest of Westlake Park, in case deep wells strike a local flexure similar to that in the Salt Lake field, such wells should yield large quantities of oil and gas. If the disturbance or fracture before mentioned as occurring in the vicinity of the lagoon does not have a northwestern extension, terminating the Salt Lake flexure and the productive zone on its northwest flank, then it appears highly probable that deep wells will strike productive sand in the southern part of sec. 20 and the northern parts of secs. 29 and 30, T. 1 S., R. 14 W.

Development.—There are at the present time between 75 and 80 productive or drilling wells in the Salt Lake field, belonging to the following companies: Salt Lake Oil Company, about 50 or 55; Arcturus Oil Company, 9; Utah Oil Company, 1 (these three companies controlled by the Associated Oil Company); A. F. Gilmore, 4; Pacific Light and Power Company, 4; E. P. Clark Oil Company, 7. In addition to the wells mentioned above there are several comparatively shallow small producers, belonging to the last-named company. These are located near the northern half of the line separating secs. 28 and 30 and are pumped intermittently. The wells northwest of the Salt Lake flexure vary from 1,200 to over 3,100 feet in depth. The deeper wells are as a rule the more productive and yield the lighter oil. The individual wells produce from 20 to over 1,000 barrels a day, the average being somewhere in the neighborhood of 200 barrels. Owing to the tremendous gas pressure in this field, nearly all the wells "gush" when they first come in, and it is said that one of the deep wells produced about 18,000 barrels a day for a short time after its inception. The gravity of the oil varies from 11° to 22°, the heaviest oil coming, it is said, from an isolated sand below the regular productive zone. The average for the field is between 16° and 18°.

Production, storage facilities, and transportation.—The production of the Salt Lake field has risen from a few thousand barrels in 1902 to something over 2,000,000 barrels in 1905. Facilities for handling and storing the oil have kept pace with the increase in production until at the present time the storage capacity of the field is about 390,000 barrels, 20,000-barrel to 55,000-barrel steel tanks being largely used. An 8-inch pipe line connects the field directly with Los Angeles, and smaller lines run from some of the properties to tanks and racks on the line of the Los Angeles Pacific Electric Railroad, immediately south of the field. The oil is used principally in supplying the local Los Angeles market, although considerable quantities are said to be shipped to outside points.

The large quantities of gas which come from the wells are used mainly for the generation of power for operating and development, although a small amount is used in the field for domestic purposes.

THE NINEVEH AND GORDON OIL SANDS IN WESTERN GREENE COUNTY, PA.

By Frederick G. Clapp.

INTRODUCTION.

Location.—The area discussed in the present paper is located in the extreme southwest corner of the State of Pennsylvania, midway between Moundsville, W. Va., Waynesburg, Pa., Mannington, W. Va., and Washington, Pa. The interest of the region lies chiefly in the fact that several geologic horizons underlying the surface have proved productive of oil and gas. The Nineveh, Bristoria, and New Freeport oil fields and the Richhill and Hoovers Run gas fields are situated here.

General statement.—Field and office work in 1904–5 by the writer and Frank W. De Wolf has given a better understanding of the oil and gas sands of this region, and demonstrated some errors in the drillers' identifications of certain sands. By careful study of a great number of well sections throughout this and adjoining areas it has been found that the oil horizon known by the name of "Gordon sand" in western Greene County is not equivalent to the sand of that name in the Washington oil field several miles northeast. The purpose of this report is to correct previous errors in such identifications.

PREVIOUS IDENTIFICATION OF SANDS.

The Gordon sand was first discovered in southwestern Pennsylvania in a well on the Gordon farm near Washington, drilled in August, 1885. This well lies in the Washington oil field, which for several years produced large quantities of oil from the Gantz, Fifty-foot, and Gordon horizons. The Gantz well in that field penetrated the Gordon sand 2,416 feet below the surface, or 244 feet below the top of the Gantz sand. During subsequent drilling both these horizons and also the Fifty-foot sand were traced from Washington into eastern Washington and Greene counties, and the names given at Washington came to be used over large areas in western Pennsylvania.

Thus it happened that when operations first commenced in the Nineveh field, in western Greene County, the names Gordon and Fourth were applied to sands which were then supposed to be equivalent to the beds bearing those names at Washington. In the Richhill gas field, several miles southwest of Nineveh, and occasionally in the Nineveh oil district, the name "Nineveh," "Nineveh Thirty-foot," or simply "Thirty-foot" sand has sometimes been used for the sand called Gordon at Nineveh. The name Nineveh is said to have been first used by Mr. John Worthington, and it seems to be the most appropriate name for this sand, which lies 75 to 100 feet above the true Gordon sand and 100 feet below the top of the Fifty-foot sand. This name has been used by most of the drillers of the Natural Gas Company of West Virginia in the Richhill field. In some other parts of western Greene County, in particular by certain drillers, the names Nineveh and Gordon have been correctly used. Such is true of a majority of the wells in Wayne Township and of a few in Center, Morris, and Springhill townships.

Throughout the Nineveh, Bristoria, and New Freeport oil fields, extending from Nineveh southwestward to Higbee and then southward to the West Virginia line south of Deep Valley, however, the name "Gordon" has been more generally given to the Nineveh sand.

The term "Fourth sand" has generally been applied to the true Gordon sand, and the name "Gordon Stray," when not used for the Nineveh, has designated any bed a short distance above what the drillers considered the Gordon sand.

CORRECT IDENTIFICATION OF SANDS.

Previous discussion of this question.—The only published intimation of a possible mistake in correlation of these sands is a statement by I. C. White,[a] in which he expresses some doubt on the subject, as follows:

> The oil sand struck at 2,935 feet in the Smith well, 2,049 feet below the Pittsburg coal, by Mr. Worthington, in July, 1888, was identified by him as the Gordon sand of Washington County to the north, and has ever since been so designated by the oil fraternity, having proved productive of oil and gas in a nearly continuous belt from Nineveh southwestward into Wetzel and other counties of West Virginia for a distance of 50 to 60 miles or more.
>
> Mr. Worthington and others (the writer included) have sometimes thought it possible that this very productive horizon of the New Freeport district in Greene County might not represent the Gordon sand of Washington, but possibly the "Thirty-foot" sand between it and the "Fifty-foot" horizon. But this inference is formed only upon the lessened interval (2,050 feet instead of 2,100 feet) between the sand in question and the Pittsburg coal, but as this interval is but 50 feet less than at Washington, and is the same as it is in Butler County, between the Pittsburg coal and the great Third oil sand of the Butler, Armstrong, Clarion, and other producing fields of the Venango sand region to the northeast, it appears quite probable that the original identification as given in I 5 is correct. At any rate, it is the nomenclature universally used by the oil-producing interests in Greene, Wetzel, Marshall, Tyler, and Doddridge counties.

To I. C. White, therefore, belongs the credit of having first questioned in print the correlation. The evidence collected by the present writer, and given as follows, may be regarded as decisive proof of the correct correlations:

Evidence from comparison of well sections.—In studying the underground stratigraphy of Washington and Greene counties a great number of well records have been plotted on a uniform scale and placed side by side with the various persistent horizons, such as the Pittsburg coal and Big Injun sands, in agreement.

The following table shows the important beds encountered by the drill and used in this correlation. The principal datum horizon of the region and the one used by all drillers in measuring to the various sands is the Pittsburg coal, which lies from 300 to 1,300 feet below the mouth of the well. Other beds which are easily recognized are the Little Lime and Big Lime, the Big Injun sand, and the various beds of red shale.

Drillers' terms for oil and gas rocks, etc., and their geologic correlations.

Geologic formation.	Name applied by drillers.	Geologic name.	Approximate maximum thickness.	Approximate minimum and maximum intervals to top of bed from Pittsburg coal.[b]	Correlation with sands in neighboring fields.
			Feet.	*Feet.*	
Washington	Washington coal	Washington coal	3	+420-550	
	Bluff sand	Waynesburg sandstone.	60	+330-450	
Monongahela	Waynesburg coal	Waynesburg coal	5	+270-400	
	Mapletown coal	Sewickley coal	8	+90-120	
	Pittsburg coal	Pittsburg coal	10	0	
Conemaugh	Murphy sand	Morgantown sandstone.	30	−170-240	
	Little Dunkard sand.	Saltsburg sandstone.	100	−300-420	
	Big Dunkard or Hurry-up sand.	Mahoning sandstone.	150	−420-600	

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[a] Rept. Geol. Survey West Virginia, vol. 1 (a), 1904, p. 132.

[b] + indicates above Pittsburg coal; − indicates below Pittsburg coal.

Drillers' terms for oil and gas rocks, etc., and their geologic correlations—Continued.

Geologic formation.	Name applied by drillers.	Geologic name.	Approximate maximum thickness.	Approximate minimum and maximum intervals to top of bed from Pittsburg coal.	Correlation with sands in neighboring fields.
			Feet.	*Feet.*	
Allegheny	Upper Freeport (Connellsville) coal.	Upper Freeport coal.	(?)5	– 570–670	
	Gas sand	Freeport, Kittanning or Clarion sandstone.	150	– 650–850	
Pottsville	Salt sand	Pottsville sandstones.	(?)200	– 850–950	
		Unconformity.			
Mauch Chunk	Red rock or shale.	Mauch Chunk shale.	150	– 960–1,060	
	Little Lime (or Salvation sand).	Greenbrier limestone.	100	– 960–1,160	Salvation sand = Maxton sand.
	Pencil Cave				
	Big Lime				
Pocono	Big Injun sand	Burgoon sandstone.	300	–1,070–1,300	Mountain sandstone.
	Thirty-foot sand		100	–1,700–1,900	Berea or Butler County gas sand.
	Red shale	Bedford (?) shale.	20	–1,800–1,980	
	Gantz sand		40	–1,850–1,950	Hundred-foot sand or First sand.
	Fifty-foot sand		60	–1,900–2,030	
Chemung	Nineveh, or Nineveh 30-foot sand.	Catskill beds	40	–2,000–2,120	Mistaken for Gordon in this area.
	Red rock		20	–2,000–2,140	
	Gordon Stray sand.		40	–2,100–2,250	
	Gordon sand		100	–2,080–2,290	Third sand, sometimes mistaken for Fourth sand.
	Fourth sand		40	–2,150–2,320	
	Fifth sand		40	–2,220–2,350	McDonald sand.
	Bayard sand		12	–2,350–2,480	Sixth sand.
	Elizabeth sand		10	–2,400–2,550	

In studying the wells with a view to tracing the sands, a line of wells was taken, beginning at the original Gantz well, near the Gordon well in Washington, and extending southward to the Fonner field and thence to all parts of western Greene County. In this tracing the Gordon sand was found to maintain its interval of 150 to 200 feet below the top of the Fifty-foot sand and to lie below the sand hitherto called "Gordon" in the Nineveh oil field. In the Gantz well the Nineveh sand is not recorded, but in the Baker well near Lone Pine, midway between Washington and the Greene County line, the sand occurs 102 feet below the top of the Fifty-foot sand. In that region and very frequently throughout eastern Washington County the name Gordon Stray has been applied to the sand at this horizon. In the Baker well the sand attains an unusual thickness. South of this well the next good section in line is that of the Fonner No. 2. In this well the Nineveh sand consists of 13 feet of red sand lying 48 feet below the top of the Fifty-foot; a second red rock occurs 68 feet below it and a few feet above the Gordon sand. The John Lewis well, 2.2 miles north of Nineveh, offers the next complete record, and this is the farthest well northeast in which the mistake in correlation is known to have been made. The term Gordon has been used by the drillers to designate the Nineveh sand. From the Lewis well this sand can be traced almost continuously the entire length of the oil district, being known to the drillers in this county either as "Gordon" or "Gordon Stray."

Evidence from position of Catskill red beds.—The accuracy of the tracing is facilitated by several red shales and other beds associated with the sands. The most important of these is a thin red bed which generally lies directly below the Nineveh sand. Sometimes, as in the Fonner well, the Nineveh sand itself is red. This horizon is not always red, but the color occurs so frequently that when carefully correlated there is little danger of making a permanent mistake in identifying the Nineveh sand over any considerable area. This horizon is regarded as the top of a series of red beds recognized beneath large areas in western Pennsylvania, and known to geologists as the Catskill beds, which attain a maximum thickness of 200 to 300 feet in eastern Greene and Washington counties, but die out toward the west, so that in western Greene County the horizon is marked only by the bed of red shale mentioned above and occasionally by one or two other thin red beds. The western limit of the Catskill beds, therefore, can be said to correspond approximately with the western boundary of the State of Pennsylvania.

Evidence from position of Bedford (?) *red shale.*—A second horizon of red shale—not one of the Catskill beds, but one which assists in correlations—is a bed which lies between the Thirty-foot and Gantz (or Fifty-foot) sands and which occurs rather extensively in western Greene and Washington counties and to the northwest. Toward the east it dies out. This fact was recognized by John F. Carll in the Seventh Report on the Oil and Gas Fields of Pennsylvania,[a] and he published a map showing the distribution of this bed and tracing it beneath the counties of Forest, southern Venango, and western Butler in Pennsylvania, and in eastern Ohio as far west as its outcrop along the Cincinnati anticline. By Carll the bed was provisionally correlated with one of the Bedford shales of Ohio. Since Carll's report was issued considerable drilling has been done in Washington and Greene counties, and the red shale is here found to be present considerably outside his southeastern boundary for it. In western Greene County this bed occurs from 30 to 80 feet above the top of the Fifty-foot sand and helps in the identification of this sand.

Evidence from the persistency of the Nineveh sand.—In Washington and Greene counties several sandstone horizons occur within the limits of the rocks designated as Catskill. These are generally not persistent over wide areas, owing to the fact that by nature they are lentils in the Catskill formation, dying out toward the east. The Gordon Stray, Gordon, and Fourth sands are such beds, and do not seem to be persistent. The next lower bed, or Fifth sand, and the next higher sand, the Nineveh, are much more regular, and can be traced for great distances.

Evidence from intervals.—As explained above, the interval of the Nineveh sand from the Pittsburg coal runs from 1,997 to 2,121 feet, and the distances of the Gordon sand from the coal vary between 2,023 feet and 2,287 feet. The figures for the Nineveh sand and their averages are given by townships in the following table:

Intervals from Pittsburg coal to Nineveh sand in western Greene County (in feet).

Township.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
Morris	2,028	2,110	2,055	6
Richhill	1,997	2,054	2,036	32
Center	2,005	2,120	2,039	8
Jackson	2,024	2,065	2,044	66
Aleppo	2,018	2,098	2,056	101
Wayne	2,033	2,045	2,039	2
Gilmore	2,065	2,113	2,089	2
Springhill	2,033	2,121	2,052	94
General average	....	....	2,051	....

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[a] Second Geol. Survey Pennsylvania, Rept. I, 1890, pp. 95-96, Pl. V.

The figures representing the interval of the Gordon sand below the coal are somewhat more variable in their extremes than these. They run in general as follows:

Intervals from Pittsburg coal to Gordon sand in western Greene County (in feet).

Township.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
Morris	2,100	2,141	2,133	6
Richhill	2,094	2,155	2,136	17
Center	2,083	2,170	2,127	8
Jackson	2,070	2,175	2,111	16
Aleppo	2,110	2,183	2,157	30
Wayne	2,133	2,287	2,213	13
Gilmore	2,177	2,189	2,181	3
Springhill	2,130	2,205	2,166	8
General average	....	....	2,153	....

From a comparison of the figures in the foregoing tables it will be seen that, while the Gordon sand in its averages for the various townships in this part of the county varies between 2,111 and 2,213 feet, amounting to a difference of 102 feet, the Nineveh sand, on the other hand, differs in its averages by only 53 feet. It will be noticed that none of the averages given in the table for the Gordon sand approach within 20 feet of the highest figures given in the Nineveh table, and the general averages of each table differ by over 100 feet. The overlapping of several of the figures in the maxima and minima columns is due to local variations or to inaccuracies in the drillers' measurements.

From the foregoing discussion it can be seen that there is little danger of confusing these two sands when proper care is taken in making interpretations.

SURVEY PUBLICATIONS ON PETROLEUM AND NATURAL GAS.

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BOUTWELL, J. M. Oil and asphalt prospects in Salt Lake basin, Utah. In Bulletin No. 260, pp. 468–479. 1905.

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——— The petroleum fields of California. In Bulletin No. 213, pp. 306–321. 1903.

FENNEMAN, N. M. The Boulder, Colo., oil field. In Bulletin No. 213, pp. 322–332. 1903.

——— Structure of the Boulder oil field, Colorado, with records for the year 1903. In Bulletin No. 225, pp. 383–391. 1904.

——— The Florence, Colo., oil field. In Bulletin No. 260, pp. 436–440. 1905.

——— Oil fields of the Texas-Louisiana Gulf coast. In Bulletin No. 260, pp. 459–467. 1905.

FULLER, M. L. The Gaines oil field in northern Pennsylvania. In Twenty-second Ann. Rept., pt. 3, pp. 573–627. 1902.

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——— Structural work during 1901–1902 in the eastern Ohio oil fields. In Bulletin No. 213, pp. 336–344. 1903.

HAYES, C. W. Oil fields of the Texas-Louisiana Gulf Coastal Plain. In Bulletin No. 213, pp. 345–352. 1903.

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McGEE, W J. Origin, constitution, and distribution of rock gas and related bitumens. In Eleventh Ann. Rept., pt. 1, pp. 589–616. 1891.

OLIPHANT, F. H. Petroleum. In Nineteenth Ann. Rept., pt. 6, pp. 1–166. 1898.

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PHINNEY, A. J. The natural gas field of Indiana, with an introduction by W J McGee on rock gas and related bitumens. In Eleventh Ann. Rept., pt. 1, pp. 579–742. 1891.

RICHARDSON, G. B. Natural gas near Salt Lake City, Utah. In Bulletin No. 260, pp. 480–483. 1905.

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SCHRADER, F. C., and HAWORTH, E. Oil and gas of the Independence quadrangle, Kansas. In Bulletin No. 260, pp. 442–458. 1905.

STONE, R. W. Oil and gas fields of eastern Greene County, Pa. In Bulletin No. 225, pp. 396–412. 1904.

TAFF, J. A., and SHALER, M. K. Notes on the geology of the Muscogee oil fields, Indian Territory. In Bulletin No. 260, pp. 441–445. 1905.

WEEKS, J. D. Natural gas in 1894. In Sixteenth Ann. Rept., pt. 4, pp. 405–429. 1895.

WILLIS, BAILEY. Oil of the northern Rocky Mountains. In Eng. and Min. Jour., vol. 72, pp. 782–784. 1901.

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KINDLE, E. M. Salt and other resources of the Watkins Glen quadrangle, New York. In Bulletin No. 260, pp. 567–572. 1905.

RUSSELL, I. C. Notes on the geology of southwestern Idaho and southeastern Oregon. Bulletin No. 217. 83 pp. 1903.

STONE, R. W. Mineral resources of the Elders Ridge quadrangle, Pennsylvania. Bulletin No. 256. 86 pp. 1905.

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In addition to the references given to the mineral resources of the United States, those for the years not mentioned will be found to contain articles on oil, natural gas, and asphalt. The latest and most important articles have been cited.

ASPHALT.

OZOKERITE DEPOSITS IN UTAH.

By JOSEPH A. TAFF and CARL D. SMITH.

LOCATION.

The only known deposits of ozokerite in Utah are located in the north end of the Wasatch Plateau, near the Denver and Rio Grande Railroad. This mineral wax occurs here in three groups of localities—(1) in the vicinity of Colton, on the north side of Price River Valley; (2) near and to the east of Soldier Summit, where the railroad crosses the crest of the plateau; (3) near Midway station, on the north side of the canyon, near the source of Soldier Creek and west of Soldier Summit. Colton is 7 miles southeast and Midway 3 miles west of Soldier Summit.

FEATURES OF THE COUNTRY.

The Colton and Soldier Summit localities are in Price River Valley, which trends toward the southeast, and has here a rather broad, flat channel. On the southwest the slopes rise gradually with the inclination of the strata. On the opposite side, toward the northeast, beginning half to three-fourths of a mile from the river, the ascent is more abrupt and is made in a succession of high benches and knobby spurs to the crest of the Roan Cliffs. Midway station is in a gorge that trends westward near the source of Soldier Creek. Ozokerite deposits occur in the gulches making into the valley from the north side. The surface of the country is clothed with sagebrush except in the upper stretches of the gulches and valleys facing toward the north and west, where groves of aspen, chokecherry, service, and scattering pines grow.

GEOLOGIC RELATIONS.

The ozokerite deposits occur in shales, shaly sandstones, and limestone strata in the lower part of the Tertiary deposits of the "Wasatch" group. The mineral has been found at various positions through a section of about 500 feet of strata. The shales are friable, variously tinted purple, green, blue, and white. The sandstones are moderately soft, and light drab and brown in color. The limestone beds are thin and brittle, and vary from white to shades of yellow and blue. The limestone deposits occur both below and above the section containing ozokerite.

The rocks are uniformly tilted toward the northeast about 5°. At the localities inspected near Colton, Soldier Summit, and Midway the strata are intersected by fissures and zones of brecciation and parallel jointing. These fissures and spaces between brecciated rock contain the ozokerite, usually as thin films and sheets but locally as dike-like bodies several inches thick, and it is reported several feet thick in places. The faces of the fissures and also the brecciated portion of the rock show the effects of movement in slickensided surfaces. In many instances also the surfaces of the ozokerite deposits exhibit the same phenomena. The vertical displacements along these fissure veins, so far as could be determined, have been slight where the inspection was made in the mines and prospects. The study of the surface conditions did not reveal appreciable faulting. The fissures and joint planes are almost vertical, and near Colton and Soldier Summit they bear approximately N. 10° W. One-half mile west of Midway station a fracture zone containing ozokerite bears N. 30° W. Another half a mile northeast of the same station has a trend N. 60° W. In both instances the fractures were almost vertical.

Though the ozokerite has been mined or prospected at several points through a stratigraphic range of nearly 500 feet, it has not been shown that there is any systematic variation in the thickness of the deposits. It has been found to be locally variable both laterally and vertically.

NATURE OF THE MINERAL.

Three samples were selected for laboratory tests, one from the mine half a mile northeast of Midway station, a second from the mine at Colton, and a third from the mine 1½ miles north of Colton. These samples were subjected to fusion and solution tests made in the Geological Survey laboratory by Eugene C. Sullivan.

The mineral occurring near Midway and Soldier Summit and at the mine in the town of Colton has essentially the same physical appearance. The slight variations in hardness and color are not greater than are found to occur at a single locality. In places the ozokerite has been crushed and intimately slickensided, as is the case with the material collected from the Colton mine. The mineral is thereby rendered more friable than where such pressure and movement of contact strata has not occurred. Under ordinary conditions the mineral is semibrittle and slightly friable, but a mass can not be crushed or molded between the fingers. It cuts easily, somewhat like hard cheese, but does not adhere to the knife. It is for the most part black, and here and there yellowish resinous parts blend with the black. In the Midway mine certain parts were distinctly fibrous and yellow, as if a purer material had been blown into or had percolated through open spaces in the darker product.

The mineral at the Midway locality melts at 64° C., is completely soluble in boiling ether, and has a faint petroleum odor. The Colton product melts at 70° C., is incompletely soluble in boiling ether, and has no odor. The material of the third test, from the deposits 1½ miles north of Colton, is entirely black, has a pronounced petroleum odor, and can be molded in the fingers. Its melting point is 54° C., and it is completely soluble in boiling ether. The mineral from this locality, as well as from others in the vicinity north and northeast of Colton, contained more bitumen or asphalt than the Midway and Colton samples, which accounts for its lack of color, softness, and lower melting point. In concluding his report on the tests of the samples, the chemist remarks that they behave like paraffin on heating, and are ozokerite or closely related substances.

DEVELOPMENT.

The pioneer work and a large part of the development of ozokerite in this region are due to the efforts of Mr. R J. Kroupa, who began prospecting in the vicinity of Midway in 1886. Mr. Kroupa, who now lives at Provo City, Utah, gave material aid to the writers in the investigation of the ozokerite deposits.

Ozokerite has been exploited commercially at five and probably more localities in this field. Many prospects in the neighborhood of these mines have been made, showing the presence of the mineral. From a few of these surface workings it is reported that a considerable quantity of ozokerite has been removed. Five mines have been equipped with more or less complete facilities for exploitation, and three plants have been established for separating the product from the associated rock materials.

Colton district.—One of the mines in this district is located at Colton. A shaft is sunk on a vertical shear zone 5 to 6 feet in width to a depth of 110 feet and is equipped with a 10-horsepower hoisting engine. Drifts have been run on the strike of the fractures at a depth of 45 feet and at the base. The mine is now closed, it is claimed, on account of litigation. At the time of inspection it was filled with water below the 45-foot drift. At this level the brecciated zone consists of broken green and purple shale with sandstone fragments. Ozokerite occurs in scales or thin veins or as pockets and veins of variable extent and width not exceeding a few inches at most. Several hundred pounds of the commercial product are on hand and it is reported that the total output has been about 10 tons.

Another mine has been operated 1½ miles northeast of Colton, very near the southwest corner of sec. 13, T. 11 S., R. 8 E. It is on a different fracture zone from that of the Colton mine and nearly 500 feet higher in the strata. At this place a tunnel has been driven 225 feet N. 10° W., on a shear zone of brecciated sandy shale 4 to 6 feet wide. At the end of the tunnel a drift is driven 125 feet toward the east. A space of vertical fractures is crossed in this drift 65 feet east of the tunnel. A shaft said to be 100 feet in depth has been sunk at the mouth of the tunnel and drifts run north and south at a depth of 60 feet. The faces of the fractured shale showed much slickensiding. Small quantities of ozokerite occur here and there as thin films in the joints both in the tunnel and in the drift. The developments here are recent, but the plant was not in operation when visited.

A third mine in the Colton district is 1½ miles north of Colton and very near the north side of the SW. ¼ sec. 14, T. 11 S., R. 8 E. At this point a tunnel was driven N. 10° W., following a line of vertical fractures. Ozokerite occurs here in thin sheets following joints and surrounding fragments of brecciated shale. Several prospects have been made on the same line of fissures in the vicinity, exhibiting similar conditions in the occurrence of the mineral. Prospects showing the presence of ozokerite have been made in the SE. ¼ SE. ¼ sec. 14 and the NW. ¼ SE. ¼ sec. 15, and mining to a limited extent has been carried on in the SW. ¼ NW. ¼ sec. 24, T. 11 S., R. 8 E., on similar north-south lines of jointed and fissured strata. Nowhere in the Colton district has ozokerite been seen by the writer in bodies more than a few inches in thickness.

Soldier Summit locality.—The development of ozokerite in this locality is limited to the NW. ¼ sec. 30, T. 10 S., R. 8 E., within half a mile east and northeast of Soldier Summit. A mine has been equipped with hoisting power and in connection with it a concentration plant erected nearly one-third of a mile east of Soldier Summit. The mine was closed at the time visited, on account of reported litigation. Mr. Kroupa, who directed the development here, reports that the shaft is 225 feet in depth and was driven on a band of vertical fissures that contained the mineral wax, and that drifts had been opened 50 feet to the north and south on the strike of the fractures. A north-south shear zone has been prospected one-fourth mile south of the mine. In all cases here the ozokerite is reported to occur in veinlets filling narrow fissures in the strike of the crushed strata and surrounding the brecciated shale and shaly sandstone. Locally the veins swell to a thickness of nearly 3 feet, according to Mr. Kroupa's verbal report.

Midway locality.—Two small mines have been driven on vertical fractures on shale, one situated half a mile west and another half a mile northeast of Midway station. The fracture zone in the first instance is 2½ feet wide and bears N. 30° W. In the other the fractured strata are 4 to 5 feet wide and bear N. 60° W. The ozokerite occurs at three places as variably thin sheets in vertical fissures and surrounding fragments of brecciated rock, in a similar manner to that at Colton and Soldier Summit.

METHODS OF CONCENTRATION.

The manner of separating ozokerite from the associated rocks is a simple process. The plant as described by Mr. Kroupa consists of a steam boiler and engine, a crusher, and steam-heated vats. The soft rock and ozokerite mixture is crushed and run into long vats with narrow bottoms containing water kept at a boiling temperature. The ozokerite melts at a temperature of 54° to 70° C., and floats off as a liquid into cooling vats, while the rock is driven out along the narrow bottom of the vat by revolving screws. On cooling the ozokerite is remelted in dry pans to remove the content of moisture.

CONCLUSION.

In conclusion it is well to remark that the extent, either in thickness or length, of the occurrence of ozokerite, as of any other species of the hydrocarbon series found filling fissures or spaces between broken rock, can not be relied on far beyond the limit of prospected ground. Both the width of the fissured or fractured zone and the occurrence of ozokerite are found to be variable. In no instance in this field have ozokerite veins been reported to exceed 3 feet in width. Usually, as has been stated, the mineral is in the form of thin sheets or veinlets in fissures or spaces surrounding brecciated rock. It is evident that for profitable exploitation such ozokerite-bearing ground should contain sufficient mineral wax to form approximately 10 per cent of the rock removed for treatment.

SURVEY PUBLICATIONS ON ASPHALT.

The following list contains the more important papers relative to asphalt, published by the United States Geological Survey or by members of its staff:

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ELDRIDGE, G. H. The uintaite (gilsonite) deposits of Utah. In Seventeenth Ann. Rept., pt. 1, pp. 909–949. 1896.

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PORTLAND, NATURAL, AND PUZZOLAN CEMENTS.

CEMENT RESOURCES OF THE CUMBERLAND GAP DISTRICT, TENNESSEE-VIRGINIA.

By EDWIN C. ECKEL.

General statement.—In January, 1906, a short time was spent in the examination of the cement resources of the Cumberland Gap district. Here, in Claiborne County, Tenn., and Lee County, Va., heavy beds of nonmagnesian limestone and shales are exposed along the southeastern flank of Cumberland Mountain. Near Cumberland Gap these beds are particularly well located from a cement manufacturer's point of view, being accessible to two railroads and within 9 miles of the important Middlesboro coal district. These advantages seemed to justify careful examination of the area and the present brief report summarizes the writer's conclusions in regard to the matter. It is a pleasure to acknowledge the courtesies extended by the officials of the American Association, the Virginia Iron, Coal, and Coke Company, the Louisville and Nashville Railroad, and the Southern Railway. Mr. J. H. Bartlett, of the American Association, furnished detailed maps of the district and some analyses of the limestones and shales, and also, by request, had several sections measured and platted by his engineers. Further analyses of the limestones, shales, and iron ores of the district were obtained from the manager and chemist of the Middlesboro plant of the Virginia Iron, Coal, and Coke Company.

Geology of the district.—The rocks of the district include Silurian, Devonian, and Carboniferous formations, dipping mostly to the northwest at angles of 15° to 35°. The section exposed in the district, from above downward, may be generalized as follows:

Geologic section near Cumberland Gap.

	Thickness in feet.
Coal Measures: Shales and sandstones with coal beds.	
Lee conglomerate: Massive sandstone and conglomerate	1,000-1,100
Pennington shale: Greenish shales and thin sandstone	50- 150
Newman limestone: Heavy-bedded blue and gray limestone	250- 400
Grainger shale: Gray to greenish shales	50- 125
Chattanooga shale: Black carbonaceous shales	150- 300
Rockwood formation: Shales and sandstones, with beds of red hematite	400- 700

Areal distribution of the formations.—Of the formations above tabulated, the Coal Measures outcrop only in the area northwest of Cumberland Mountain. The crest and northwest flank of this mountain are formed by the massive beds of the Lee conglomerate. Underlying the conglomerate, near the top of the southeastern flank of the mountain, is a relatively thin bed of the Pennington shale. Below this, and usually forming the middle part of the slope, are heavy beds of Newman (Lower Carboniferous) limestone. The Grainger and Chattanooga shales outcrop on the lower slopes of the mountain and in the valley (Poor Valley) at its foot; while the Rockwood beds commonly make up the Poor Valley Ridge just southeast of this valley.

Available limestone.—The Newman (Lower Carboniferous) formation in this district is a series of heavy-bedded blue to gray limestones, the entire section showing a thickness of 250 to 400 feet. Cherty beds occur at several horizons in this limestone, but the mass of the rock is fairly pure and low enough in magnesia to furnish a satisfactory raw material for Portland cement manufacture.

Analyses of limestone near Cumberland Gap, Tennessee.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Silica (SiO_2)	1.40	1.86	5.05	4.20	2.00	2.80	1.32	4.12	0.74	5.78
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	1.00	.96	1.86	1.50	1.00	.90	1.23	.42	.[illegible]4	.46
Lime carbonate ($CaCO_3$)	94.57	94.85	90.05	89.54	94.57	91.72	95.62	87.10	95.50	90.90
Magnesium carbonate ($MgCO_3$)	3.03	2.33	3.04	4.76	2.50	4.58	1.32	3.30	2.79	1.46
Sulphur trioxide (SO_3)	n. d.	n. d.	n. d.	n. d.	n. d.	n. d.	.51	n. d.	n. d.	n. d.
Water	......	......	......	......	......	......	......	2.21	.44	1.28

1–6. Analyses by W. Rosenfeld, chemist Virginia Iron, Coal, and Coke Company.

7. Analysis by L. F. Barnes.

8–10. Analyses by J. Sanderson, chemist Watts Iron and Steel Company.

Available shales.—The shales required for cement can be obtained from four different geologic groups—the Coal Measures, the Pennington shales, the Grainger shales, or the Chattanooga shales. Each of these formations is well exposed in this vicinity. The latter three outcrop along the southeastern flank of Cumberland Mountain and the shales of the Coal Measures outcrop in the Middlesboro basin northwest of that ridge. The shales will be briefly described in geologic order.

The Chattanooga (Devonian) shale formation is in this district 150 to 400 feet thick. It consists of brittle black carbonaceous shales or slates, often containing small percentages of pyrite. Some beds, therefore, contain too much sulphur to be entirely satisfactory as cement material, but the mass of the formation is good enough so far as its sulphur content is concerned. These shales are rarely sandy, and their silica percentage often falls so low that the following ratio is obtained:

$$\frac{\text{Silica}}{\text{Alumina}+\text{iron oxide}}=2.25$$

While material with this silica-alumina ratio can be used in cement manufacture, the shales next to be considered would seem more satisfactory.

The Grainger formation, lying above the Chattanooga shales and below the limestone, varies from 50 to 125 feet in thickness. It is composed of gray to greenish shales, siliceous enough on analysis, but with no coarse sandy beds. For this reason this shale is probably the most satisfactory as a cement material.

Analysis of Grainger shale, Cumberland Gap, Tennessee.

Silica (SiO_2)	74.00
Alumina (Al_2O_3)	13.50
Iron oxide (Fe_2O_3)	3.40
Lime carbonate ($CaCO_3$)	2.01
Magnesium carbonate ($MgCO_3$)	1.53

The above analysis was made in 1904 by J. G. Harding, of Wellston, Ohio, on a sample of shale taken a few feet below the limestone in the Morrison quarry. It is obviously a very satisfactory shale for use in Portland cement manufacture, owing to its composition, giving the following ratio:

$$\frac{\text{Silica}}{\text{Alumina}+\text{iron oxide}}=\frac{74.00}{16.90}=4.38$$

The Pennington shale formation, which overlies the limestone, is here from 50 to 150 feet thick. It consists of beds of greenish shales, with alternating thin layers of sandstone.

While it is probable that by careful grinding this material could be utilized for cement manufacture, it is not regarded as being so satisfactory as the Grainger shales, which underlie the limestone formation.

In the Coal Measures of the Middlesboro district, immediately west of Cumberland Mountain, shale beds occur at many localities. At the Harkness Brick Works, 8 miles northwest of Cumberland Gap, some of these Carboniferous shales have been utilized. Analyses of these shales, by A. H. Phillips, follow:

Analyses of Carboniferous shales used at Harkness Brick Works.

	1.	2.
Silica (SiO_2)	61.14	56.21
Alumina (Al_2O_3)	19.35	27.00
Iron oxide (Fe_2O_3)	5.89	2.74
Lime (CaO)	.93	.13
Magnesia (MgO)	1.87	.77
Potash (K_2O)	3.07	3.46
Soda (Na_2O)	1.54	1.58
Carbon dioxide (CO_2)	5.86	7.67
Combined water		

CEMENT RESOURCES OF WASHINGTON.

By Henry Landes.

GENERAL STATEMENT.

A decade ago the amount of cement used in the State of Washington was less than 25,000 barrels annually. In 1905, 264,982 barrels of cement were imported into the Puget Sound district. These came chiefly from Germany and Belgium. In addition, about 150,000 barrels of cement manufactured in California were shipped to Washington. The increasing demand for cement has led to many inquiries in regard to the possibilities of its manufacture in Washington, and it is the purpose of this article to describe very briefly the more important districts, so far as known, where the raw materials are found in sufficient quantities to make such an industry profitable.

Limestone, the principal ingredient necessary in the manufacture of cement, is found only in the northern counties of the State from Puget Sound to the Idaho boundary, that is, in San Juan, Whatcom, Skagit, Snohomish, King, Okanogan, Ferry, and Stevens counties. Clays occur much more widely than the limestones, but in this article only those will be referred to which lie conveniently near limestone deposits. A brief account of the clays of the State was given by the writer in Bulletin No. 260, pages 550–558. In regard to fuel, Washington is well supplied with coal suitable for use in cement manufacture. In the counties west of the Cascade Mountains coal may be had at a very reasonable cost wherever cement is likely to be manufactured. In the counties of the northeastern portion of the State it will be found that the freight charges on coal will be a serious hindrance in the manufacture of cement.

In a discussion of the cement possibilities of Washington it seems best to take up the matter by counties, from the coast eastward.

SAN JUAN COUNTY.

In San Juan County the only deposits of limestones and clays worth considering are at tide water on San Juan and Orcas islands. The principal deposits on San Juan Island are at Roche Harbor, and are the property of the Tacoma and Roche Harbor Lime Company. The largest lime works on the Pacific coast are located at this point. This lime has an established reputation because of its purity. The limestone has been rendered entirely crystalline by metamorphism, and any fossils which it may have contained have been destroyed. The limestone is one of a series of metamorphic rocks which have been greatly contorted and faulted and its geological age has not been accurately determined. It is without doubt older than the Cretaceous rocks which form the bulk of the small neighboring islands a few miles to the north.

At Roche Harbor the limestone occurs as two large ledges with a strike a little east of north. In outcrop they extend from north to south about one-half mile and from east to west about 1,000 feet. The height of the limestone above tide water averages 200 feet; its depth below the ocean level has not been determined. The fact that the limestone is much broken and that but little stripping is required makes it possible to quarry the stone and deliver it to the crusher at a minimum expense. The quarry at this place has been in operation since 1882 and the manufacture of lime amounts to about 300,000 barrels per year. The limestone varies but little in composition and is very uniform in character.

Adjacent to the limestones there are large deposits of glacial sediments which contain extensive beds of clays interstratified with sands. Some of the clay beds are known to be at least 40 feet in thickness and they have been so thoroughly washed as to be unusually free from gritty ingredients. In case the clays do not afford enough silica for use in cement manufacture it may be easily obtained from the quartzites and slates that are near at hand as members of the metamorphic series of which the limestone is a part.

A cement plant built at Roche Harbor could be so arranged that the limestone at least might be transported to the mills by a gravity system. The final product could also be transported in the same manner to warehouses on the wharf. The harbor here is well protected and the water is sufficiently deep for ocean-going vessels to enter and depart at any tide.

Analyses of limestone, clay, slate, and quartzite from Roche Harbor, Washington.

	Limestone.			Clay.		Slate.	Quartzite.	
	1.	2.	3.	4.	5.	6.	7.	8.
Silica	0.44	0.27	0.20	55.81	56.35	78.0	72.32	84.84
Iron and aluminum oxides	1.13	.21	.30	26.28	24.62	6.98	10.11	6.78
Calcium carbonate	98.21	99.06	98.57	4.34	3.66	6.45	7.75	3.63
Magnesium carbonate	....	.46	1.02	3.39	2.58	1.56	2.24	.80
Sulphur	....	....	....	Trace.	.31	Trace.	.07	Trace.
Alkalies	....	....	....	3.98	3.94	1.56	1.11	Trace.
Moisture	....	....	....	6.11	7.52	.30	.45	....
Carbonic acid	....	....	....	....	....	5.15	5.01	3.41

No. 1, made in 1888, by Moss Bay Hematite and Iron Company (Limited), Workington, England.
No. 2, made in 1893, by Puget Sound Reduction Company, Everett, Wash.
No. 3, made in 1902, by C. F. McKenna, New York City.
Nos. 5 to 8, made by F. C. Newton, Seattle, Wash.

On the northwest shore of Orcas Island there are several outcrops of limestone very similar in character and occurrence to those described at Roche Harbor, but of smaller extent. At several points quicklime has been made from time to time and the conditions for cement making are favorable. The limestone ledges lie far enough above the level of the water to make a gravity method feasible, and this could be followed at all stages of cement making from the quarry to the warehouse on the wharf. The water is very deep and large vessels may come very close inshore. As at Roche Harbor the limestone is entirely crystalline, and with its neighboring metamorphic rocks has suffered extreme folding, faulting, and other dislocations. Along the adjacent shores, conveniently near the outcrops of limestone, there are shales and beds of clay affording materials suitable for cement manufacture. Below are some analyses of limestones, shales, and clays from this location on Orcas Island, made by A. H. Cederberg:

Analyses of limestone, shale, and clay from Orcas Island, Washington.

	Limestone.		Shale.		Clay.	
	1.	2.	3.	4.	5.	6.
Silica	1.61	1.14	62.8	39.80	57.3	53.2
Iron and aluminum oxides	.04	....	19.2	21.62	21.4	23.9
Calcium carbonate	97.45	97.23	10.2	29.10	5.1	6.3
Magnesium carbonate	....	.31	.9	2.91	3.1	4.1
Sulphur	Trace.	Trace.	....	.41	.5	.8
Alkalies, etc	.51	1.21	Undet.	2.15	2.1	2.9

WHATCOM COUNTY.

In the vicinity of Kendall, on the line of the Bellingham Bay and British Columbia Railway, there are a number of deposits of limestone and clay which afford the proper materials for cement manufacture. The outcrops of limestone immediately south of the railway do not indicate large bodies, but north of the railway, at a point about 3 miles from Kendall, is a large ledge of this rock presenting a vertical face or cliff which may be seen for a distance of 2 or 3 miles. The limestone is entirely crystalline and all traces of fossils have been eliminated. This limestone, as in the case of the San Juan limestones, is a part of an extensive metamorphic series which has been greatly folded and crushed. As a result of the breaking up of the original bed of limestone on the one hand and of extensive erosion on the other the rock occurs in fragments or pockets and not in one continuous body. The amount of limestone here could be determined readily by means of the diamond drill, and this should be done before a cement plant is installed.

A few miles west of the limestone deposits and along the railroad track there are beds of glacial clay. One of these beds was explored by drilling to a depth of 50 feet. The clay is advantageously located and may be loaded on cars for transportation at a very small cost.

Analyses of limestone, clay, and slate from Kendall, Wash.

	Limestone.		Clay.		Slate.	
	1.	2.	3.	4.	5.	6.
Silica	1.52	1.37	61.27	57.06	66.01	72.69
Iron and aluminum oxides	.35	.42	25.30	26.80	17.65	22.19
Calcium carbonate	97.48	98.72	2.96	10.62	8.01	2.16
Magnesium carbonate	1.26	.26	4.68	1.13	3.15	2.47
Alkalies				2.56		

Nos. 1 and 3 made by D. W. Riedle, Montavilla, Oreg.
Nos. 2, 4, 5, and 6 made by A. H. Cederberg.

SKAGIT COUNTY.

Large deposits of limestone and clay, lying side by side, occur on the east side of Baker River about three-fourths of a mile from its junction with Skagit River. This point is 40 miles from the mouth of the Skagit, a stream which is navigable at nearly all times of the year. Transportation is also afforded by the Seattle and Northern division of the Great Northern Railway.

These deposits of limestone and clay have been purchased by the Washington Portland Cement Company and a plant for the manufacture of cement is now under construction. It is expected that the plant will be in operation by May 1, 1906. Two 100-foot rotary kilns, 7½ feet in diameter, are being installed. Rotary driers and coolers with both ball and tube mills will be used. It is planned to use oil as a fuel both in drying and in calcining. A flume nearly 3 miles in length has been constructed from Baker River to the plant, giving a head of 57 feet, capable of generating 3,000 horsepower. It is planned to manufacture from 700 to 800 barrels of cement daily at the outset. The plant has been so arranged that it can easily be enlarged to a daily capacity of 3,000 barrels.

The limestone is crystalline in character and almost pure white in color. It belongs to an extensive metamorphic series the geological age of which is undetermined. Slate lies adjacent to the limestone and the two have a strike a little west of north. The ledge of limestone dips to the southwest at an angle of about 55°. The outcrop is traceable along the strike for 600 feet and shows a width of 207 feet in cross section. The actual amount of limestone at this place is difficult to make out, because when followed along the strike it passes under a thick layer of mantle rock.

The clay lies in horizontal beds in contact with the limestone and represents silt brought down by Baker and Skagit rivers. It is well stratified and finely assorted and rests upon beds of gravel. It is light blue in color and has an average depth of 165 feet. It is exposed along Baker River for a distance of 1,350 feet.

Analyses of limestone and clay from the property of the Washington Portland Cement Company, Baker, Wash.

	Limestone.		Clay.	
	1	2	3	4
Silica	0.80	3.41	58.75	55.90
Iron and aluminum oxides	.70	1.78	25.94	25.50
Calcium carbonate	98.14	92.50	4.66	4.90
Magnesium carbonate	.65	2.30	4.47	2.83
Sulphur				.51
Alkalies			1.48	3.91
Combined water			4.60	6.45

Nos. 1 and 3 made by Prof. C. W. Johnson, Seattle, Wash.
Nos. 2 and 4 made by F. C. Newton, Seattle, Wash.

SNOHOMISH COUNTY.

Limestone occurs in a number of places in the eastern half of Snohomish County, but only at a point 3 miles east of Granite Falls, on the Everett and Monte Cristo Railway, has the rock been quarried to any extent. The stone is crystalline and is a member of an extensive metamorphic series extending in a broad belt north and south. The adjacent rocks are chiefly slates and schists. A quarry has been opened by the side of the railway track and the stone is loaded directly onto the cars. The quarry has been in operation for several years and the principal sales of rock have been made to the smelter and paper mill at Everett. A limekiln having a capacity of 100 barrels per day is in operation. The property is owned by the Canyon Lime and Cement Company. Some investigations have been made as to the possibilities for a cement factory here, but no active work has yet been done.

The following analyses were made by A. H. Cederberg:

Analyses of limestone, calcareous slate, and clay near Granite Falls, Wash.

	Limestone.	Calcareous slate.	Clay.
Silica	0.2	22.1	61.6
Iron and aluminum oxides	1.4	10.6	25.4
Calcium carbonate	98.1	59.6	7.2
Magnesium carbonate	Trace.	1.8	2.3
Sulphur		Trace.	1.6
Alkalies		1.4	2.94

KING COUNTY.

The metamorphic series of rocks occurring in Whatcom, Skagit, and Snohomish counties is continued into King County. In the vicinity of Snoqualmie Pass and at several points along the line of the Great Northern Railway, notably in the region about Baring, outcrops of crystalline limestone have been found. Very little work has been done looking to the development of any of the deposits and there is little information at hand concerning them.

So far as clay is concerned King County is particularly favored. Clays of excellent quality occur abundantly in the western part of the county, chiefly in connection with the Tertiary coal measures. At Renton, Taylor, and Kummer thick beds of shale are found interstratified with seams of coal. At all these points clay is mined for use in the manufacture of ornamental and paving bricks, terra cotta, sewer pipe, etc. So far as known deposits are concerned, the limestones and clays are too widely separated to make the manufacture of cement a profitable industry in this county. Further prospecting may reveal the presence of desirable beds of clay within or adjacent to the limestone areas.

OKANOGAN COUNTY.

In the northern portion of Okanogan County crystalline limestone has been discovered at many points in conjunction with slate, metamorphic sandstone, and conglomerate. The largest limestone areas are to the west and northwest of Riverside, where there are conspicuous cliffs of this rock with an areal distribution of several square miles. On the eastern slope of Palmer Mountain there are several bold outcrops of light-gray limestone which is only partially crystalline. Because of the difficulties in the way of transportation and the sparseness of population nothing has been done toward utilizing the limestone of this county. It is safe to assume that the neighboring argillaceous rocks could be used with the limestone in the manufacture of cement whenever a sufficient demand arises for this product in this part of the State.

FERRY COUNTY.

The geological formations of Ferry County are mainly metamorphic rocks, represented by limestones, slates, and quartzites, with many granite intrusions. Here and there small areas of sandstones and shales indicate the existence of lakes in Tertiary times. The largest limestone area is in the form of a long narrow belt which extends north and south across the country and which lies at the western foot of the granite divide separating Columbia and Kettle rivers from the streams to the west. A few miles west of Republic there is a large outcrop of a bluish limestone which is very compact and hard. A limekiln is in operation here and a high grade of quicklime is manufactured. Very near the crystalline limestone, clay and impure limestone occur, which may be utilized in cement manufacture.

The following analyses were made by A. H. Cederberg:

Analyses of crystalline limestone, impure limestone, and clay from Ferry County, Wash.

	Crystalline limestone.	Impure limestone.	Clay.
Silica	1.1	18.9	60.13
Iron and aluminum oxides	Trace.	7.2	29.10
Calcium carbonate	98.6	66.1	8.98
Magnesium carbonate	Trace.	4.5	1.36
Sulphur	....	Trace.	.75
Alkalies	....	2.1	.29

STEVENS COUNTY.

Stevens County contains very large deposits of materials necessary for cement manufacture, the only drawback being the high cost of fuel, as the latter is subject to a long transportation charge. The rocks of the county are chiefly metamorphic in character, consisting mainly of limestone or marble, slate, and quartzite. These have been greatly disturbed by folding as well as by intrusions of granite, basalt, and other igneous rocks. The limestones are usually entirely crystalline and at several places yield marble of excellent quality. The fossils they may have contained have been wholly destroyed except in one known instance, near Springdale, where the semicrystalline limestone contains coral remains which indicate its Paleozoic, probably Carboniferous, age. While these rocks are ordinarily known as limestones, many of them are really dolomites, and careful field work must be done and many analyses made in order to locate the true limestones and determine their extent.

The only place in Stevens County where active steps have been taken toward the manufacture of cement is at Box Canyon, on Pend Oreille River. It is planned to transport the cement by steamer up the river 45 miles to Newport, where the Great Northern Railway is reached. At Box Canyon there are large deposits of pure limestone and beds of excellent clay, as well as layers of natural cement rock interstratified with the pure limestone. The Pacific Portland Cement Company has acquired 262 acres of land and has expended $20,000 in preliminary work. A dam has been made across Cedar Creek about 3 miles above its confluence with the Pend Oreille at Box Canyon, and by the use of a flume and a 28-inch steel penstock with Pelton wheel about 250 horsepower is obtained. The works now under construction will have a daily capacity of 200 barrels. Analyses of the imestone and clay at Box Canyon are as follows:

Analyses of limestone and clay from Box Canyon, Washington.

	Limestone.	Clay.
Silica	1.60	64.1
Aluminum and iron oxides	Trace.	22.30
Calcium carbonate	98.50	1.69
Magnesium carbonate	Trace.	Trace.

In the vicinity of Colville, on the Spokane Falls and Northern Railway, there are some occurrences of limestone free from magnesium carbonate in harmful amounts. One of these occurrences is at a point 15 miles northeast of Colville, where the Jefferson Marble, Mining, and Milling Company has opened a quarry and established marble works. The limestone outcrops cover a broad area with extensive beds of glacial clays conveniently near. The limestone or marble exhibits many varieties of colors, from clear white through yellow, brown, and dark blue to black. The stone is fine grained and compact. Analyses of two varieties of marble, made by Prof. S. Shedd, of Pullman, are as follows:

Analyses of white and pink marble from quarry 15 miles northeast of Colville, Wash.

	White marble.	Pink marble.
Silica	0.87	3.49
Iron	None.	.24
Alumina	None.	None.
Lime	55.16	51.54
Magnesia	.21	1.11
Carbon dioxide	43.77	42.46

The property of the Keystone Marble Company lies near the locality last described, at a point 8½ miles east of Bossburg, a station on the Spokane Falls and Northern Railway. The marble outcrops over a considerable area and presents ample conveniences for quarrying. The stone exhibits great diversity in color, but on the whole approaches a pure calcium carbonate. Interstratified with the beds of marble are slates and quartzites. Analyses of two varieties of marble, made by Prof. S. Shedd, of Pullman, are as follows:

Analyses of white and gray marble from quarry 8½ miles east of Bossburg, Wash.

	White marble.	Gray marble.
Silica	0.98	0.82
Iron	Trace.	Trace.
Alumina	....	....
Lime	53.96	54.81
Magnesia	1.25	0.70
Carbon dioxide	43.76	43.56

In the vicinity of Ryan, a small station on the Spokane Falls and Northern Railway, there are many outcrops of marble. The stone makes conspicuous bluffs on both sides of Columbia River and is in an advantageous position for economical quarrying. The marble is fine grained, is mostly of a light-gray color, and is unusually hard. An analysis of the Ryan marble, made by Prof. S. Shedd, of Pullman, is as follows:

Analysis of marble from Ryan, Wash.

Silica	1.00
Iron and alumina	None.
Lime	53.96
Magnesia	1.60
Carbon dioxide	43.27

Independent of the clay represented in the slates noted as occurring in proximity to the limestones, there are many places in Stevens County where clays exist in large amounts. Some of the clays are of glacial origin, while others represent residual clays derived from granites. As a type of the latter the clays in the vicinity of Clayton may be mentioned. The numerous drill holes that have been made here show that the clay beds cover several thousand acres. There can be little question that both limestones and clays may be had in close relationships and at points convenient for transportation, so that in time Stevens County may become an important producer of cement.

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SMITH, E. A. The Portland-cement materials of central and southern Alabama. In Senate Doc. No. 19, 58th Cong., 1st sess., pp. 12–23. 1903.

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LIME AND MAGNESIA.

SOME MAGNESITE DEPOSITS OF CALIFORNIA.

By FRANK L. HESS.

INTRODUCTION.

Magnesite, while not a common mineral, is found at a considerable number of places in different parts of the world where there are large areas of serpentine, peridotites, and pyroxenites. The principal foreign deposits now worked are in Germany, Austria, Greece, Italy,[a] and India.[b] Unworked deposits are known in Lapland, Sweden, Russia, Africa, Quebec,[c] near Atlin Lake, British Columbia, and in Mexico, of which the deposits in Quebec may be altered sedimentary rocks.

In the United States the most important occurrences are in California, with lesser ones in Southern Oregon, Nevada, Pennsylvania,[d] Maryland,[e] and Massachusetts.

The Pennsylvania and Maryland deposits were at one time worked in a small way and the product used for making Epsom salts and other chemicals, but magnesite from Austria and Greece can now be imported so cheaply that they no longer pay to operate.

In California there are many deposits scattered along the Coast Range from the Oregon line to below Los Angeles, with a few along the foothills of the Sierras. Deposits are worked near Livermore and Porterville, and mines were formerly operated at Chiles Valley, Pope Valley, and in a desultory way at other points. The four places mentioned were visited by the writer in November, 1905.

COMPOSITION AND USES.

Magnesite, as it occurs in the California deposits, is a beautiful white fine-grained rock with a conochoidal fracture that looks like a break in fine china. It is magnesium carbonate, $MgCO_3$, and is about one-third harder and heavier than calcite. It contains 52.4 per cent of carbon dioxide (CO_2) and 47.6 per cent of magnesia (MgO). Like limestone, it gives off carbon dioxide on burning, and it is used for producing this gas, as the proportion contained is much greater than in limestone, which carries but 44 per cent. The residual magnesia left on burning is also more valuable than the lime left on burning limestone, and the amount of heat required to drive off the CO_2 is less. The burned magnesia (MgO) is used for making refractory brick for use with basic slags, as in copper smelting and some steel making, as an adulterant in paint, and medicinally. After being changed to the sulphite it is used in the digestion of wood pulp for paper. The light carbonate, known also as magnesia alba levis, is employed for medicinal and toilet purposes, and with varying amounts of asbestos (15 to 50 per cent of the whole) for pipe coverings and boiler lagging, As the sulphate, it is known as Epsom salts, large amounts of which are consumed in warp sizing or weighting in cotton mills and smaller amounts in medicine. The chloride is used as a cement and the hydrate in sugar making.

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[a] D'Achiardi, Giovanni, La formazione della magnesite all' Isola d'Elba: Atti della Società toscana di scienze naturale, residente in Pisa; Memorie, vol. 20, 1904, pp. 86–134, 3 pls.

[b] Eckel, Edwin C., Cements, Limes, and Plasters, their materials, manufacture, and properties, New York, John Wiley & Sons, 1905, p. 150.

[c] Hoffman, G. C., Rept. section of chemistry and mineralogy: Ann. Rept. Canadian Geol. Survey, Ottawa, vol. 13, 1905, pp. 14–19.

[d] Frazier, P., jr., Lancaster County: Second Geol. Survey Pennsylvania, vol. CCC., 1880, pp. 89, 97, 176–179, 196.

[e] Bascom, F., The geology of the crystalline rocks of Cecil County: Cecil County report, Maryland Geol. Survey, 1902, pp. 96–97.

The low price of magnesite—about $6 per ton landed at New York City—makes its mining on the Pacific coast profitable only for the local demands unless manufactured into more valuable forms. The Rose Brick Company, a subsidiary company of the American Magnesite Company, has recently established a factory at Oakland with the intention of making brick for shipment to the steel mills of the East, and other products will be manufactured by allied companies. The magnesite intended for brick will be burned in long, sloping, brick-lined steel cylinders, somewhat similar to those used for pyritic roasting. Crude oil will be used for fuel.

DESCRIPTION OF DEPOSITS.

GENERAL STATEMENT.

The California magnesite deposits, so far as known, all occur as veins in serpentine or similar magnesian rocks. By far the larger part are in the Coast Range in the serpentines that stretch from southern California into Oregon. These serpentines are probably Lower Cretaceous in age [a] and cover large areas, Becker [b] estimating that between Clear Lake and New Idria, a distance of about 200 miles, there are over 1,000 square miles of serpentine. Through a large part of this area magnesite veins of varying sizes are found. Those large enough to be more or less workable are reported from many places in Mendocino, Napa, Placer, Sonoma, Alameda, Stanislaus, Santa Clara, Fresno, Tulare, Kern, and Riverside counties. Of these the deposits in Placer, Tulare, and Fresno counties are in the foothills of the Sierras.

The serpentines of the Coast Range are ordinarily green or bluish, greatly broken and faulted, a solid block a foot in diameter being a rarity in many localities. They are derived from olivine-pyroxene rocks, in which the amounts of the minerals have varying ratios at different localities. At Porterville, the only place along the Sierra Nevada at which the serpentines were seen, they seem, from a preliminary examination, to be derived from an olivine-pyroxene rock. Instead of the usual green color, the serpentine is here brown, and as compared with the others described is remarkably solid.

Magnesite is formed from the breaking down of the serpentine, a hydrous magnesium silicate. The magnesia is dissolved by percolating waters carrying carbon dioxide, changed to the carbonate, magnesite, and precipitated in cracks and crevices as veins. The silica is carried away by the water and is often deposited in other veins as opal or quartz.

The magnesite frequently stands out prominently from the surrounding serpentine, from the fact that it seems to weather less readily than the serpentine and also that the existence of a magnesite vein generally indicates that the surrounding serpentine is considerably decomposed and so erodes rather easily. The boldness of outcrop makes the veins readily noticeable, so that their occurrence is generally known.

In the larger veins there is often a central portion of comparatively pure magnesite, while on one or both sides there may be many inclusions of serpentine. This mixed condition of the magnesite and serpentine in the veins is common among the large veins seen along the Coast Range. Small inclusions of serpentine are apt to extend well into the vein. As the side is neared the inclusions form a gradually larger proportion of the mass until the magnesite appears only as a great number of small veins in the broken serpentine. Or if the main mass is approached from the side, as along a tunnel, a stockwork of small veins of magnesite first appears, growing thicker toward the large vein, until the larger part of the mass is magnesite and the pieces of the serpentine are so separated as to become inclusions in the magnesite. Near the veins the serpentine has almost always lost its normal color and is badly rotted and porous as the result of its decomposition by percolating surface waters. The rock shrinks through the gradual removal of its components and the magnesite fills the enlarging spaces between the fragments. The magnesite formed through the decomposition of serpentine occupies about four-fifths of the space of the original rock, so that a magnesite vein may be and probably is formed very largely from the serpentine which formerly occupied the space filled by the vein, the remainder coming from the rock in a comparatively narrow zone on each side. The large width of some of the veins is thus easily explained by supposing that they occupy spaces made by the disintegrating serpentine almost as fast as they are left rather than natural fissures or cracks in the rocks. The veins are thus, in a sense, partly residual from the serpentine. Such belts of disintegration are naturally along the channels with greatest circulation of water, generally coincident with the larger faults. Every crack and joint along the line makes a feeder for the trunk channels. Among these reticulations the same process of deposition is going on, and in places sudden enlargements of the veins occur, making so-called "bowlders" of magnesite, which may be 2 or 3 feet in diameter and nearly equidimensional. This lack of linear extension in small deposits, together with the number of faults known to cross the Coast Range serpentines in every direction, makes the following of veins by widely separated outcrops very uncertain, for there is no reason to believe that sudden terminations do not occur in the large deposits as in the smaller ones.

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[a] Fairbanks, Harold W., Description of the San Luis quadrangle: Geologic Atlas U. S., folio 101, U. S. Geol. Survey, 1904, p. 6.

[b] Becker, Geo. F., Geology of the quicksilver deposits of the Pacific slope: Mon. U. S. Geol. Survey, vol. 13, 1888, p. 103.

Little is known of the depth to which the veins extend. If it is considered that they are formed through the influence of percolating surface water, it seems fair to assume that the deposits may extend down to the limit of circulation of these waters, their size being modified by the time through which such circulation has existed, any difference in the hardness or composition of the rock, etc.; and faulting is as likely to cut the veins off in depth as in length.

Cinnabar and chromite are frequently found accompanying the serpentines in the neighborhood of the magnesite deposits.

LIVERMORE DEPOSITS.

Near Livermore, a town 48 miles southeast of San Francisco, are a number of magnesite deposits, of which the only one being worked is located 32 miles southeast of Livermore and belongs to the American Magnesite Company.

An excellent road follows up Arroyo Mocho, crossing into and running down Arroyo Colorado. The maximum grade for the haul from the mine is said to be 3 per cent. At the mines the company has erected good buildings and roads, and an aerial tram 2,500 feet long, with a capacity of 100 tons per ten-hour day, delivers the magnesite to bunkers, from which it is loaded into iron wagons for hauling to Livermore. The wagons carry 17½ tons each, and two are hauled by an oil-burning traction engine. The magnesite is shipped to Oakland, where the company's factories for brick, carbon dioxide, and other products are situated. The mine offices and other buildings are located near springs that give sufficient water for the needs of the engines, the mine, and other purposes.

The magnesite veins stand out prominently in the bright sunshine of the valley and are almost dazzlingly white, so that they can be seen from the higher hills, miles away. One of the veins, called the "Mammoth," stands fully 10 feet above the hillside. Many of the veins, however, are largely covered by débris. The magnesite shows many peculiarities in weathering. Some of the surfaces weather into a pattern that looks like sun cracks in mud, with flatly oval surfaces from one-eighth to three-fourths of an inch wide between the cracks. In places there are fluted surfaces such as occur on exposed limestones, but in narrower lines, and at times the weathered surface is thickly studded with sharp points. At this place surfaces frequently are covered with a white powder which has been supposed to be magnesium oxide or hydromagnesite, but which has been determined by W. T. Schaller, of the chemical laboratory of the United States Geological Survey, to be another form of the magnesite.

Underground, nodules or portions of veins of magnesite will turn to this almost impalpable powder, leaving a core of solid material. Mr. C. H. Spinks, the superintendent of the mines, told the writer that certain other veins belonging to the company, a few miles distant, carried several feet of this powder. Why it should take this form, breaking down from the solid state without apparent chemical change, is unknown. One of the veins shows an outcrop 40 feet broad and traceable through a distance of several hundred feet. Others show lesser outcrops, but the amount exposed is large. However, in such outcrops but two dimensions are known, and an estimate of the amount of magnesite available is merest guesswork.

Although these deposits have been known for a long time, they have not been worked until the past year owing to their distance from a railroad. There are a number of veins in a group around a small valley, so arranged as to be excellently located for working by adits and an aerial tram. The first magnesite was shipped from the mine in November. The vein that is being mined strikes about N. 30° W., dipping steeply southwestward. It is pierced by several adits on different levels, and a crosscut at one place entered the vein for 35 feet without going through it. A drill hole 8 feet long at the end of the crosscut was said not to have reached the other side. The vein had been developed through a length of between 250 and 300 feet. The magnesite is pure and white, the crosscut looking as if freshly whitewashed. As is to be expected in a serpentine area, faults have occurred, cutting the vein in a number of places, both hanging and foot walls being fault planes.

Mining is carried on by means of an open cut in which the magnesite is quarried and allowed to fall through an upraise to an adit below, whence it is moved in cars to the aerial tram. The tram drops 600 feet in the 2,500 feet to the bunkers. The skips are placed 500 feet apart and each carries 1,000 pounds of magnesite.

Close to the magnesite veins are small impregnation veins of chromite, about 250 yards southeast of the present workings. The chromite occurs in grains from the size of a pea downward and can be clearly seen to spread from joints in the serpentine. The chromite is accompanied by a pale lilac-colored chlorite, probably either kotschubeite or kammererite. A small amount of work has been done on the veins, but the prospects do not seem to have been encouraging.

A little cinnabar is said to have been found in the neighborhood, and two mercury mines are being developed within a radius of 4 or 5 miles.

CHILES VALLEY.

Chiles Valley is situated in Napa County and its nearest shipping point, Rutherford, is 84 miles by rail north of San Francisco. Magnesite was mined in the valley at a point about 10 miles from the railroad by Stanley & Bartlett for twelve years, but the mines have not been operated for the last five years, being too far from the railroad to compete with points having better shipping facilities. During the time that the mines were worked many thousands of tons of magnesite were mined and burned at this place. As pure magnesite loses more than half its weight by being burned, a large saving could be made in haulage by getting rid of the carbon dioxide, if the material was to be used as magnesia. Manzanita, a hard-wooded shrub making a hot fire, was largely used for fuel.

The country rock is here also the Coast Range serpentine, somewhat more inclined to a blue-black color than at the Livermore deposits. The deposits are on the west side of the valley in a small serpentine hill skirted by a public road, and consist of a number of veins which vary in thickness from 1 foot to 6 feet and are said to have been as much as 12 feet wide. Where seen, however, the larger veins were much mixed with serpentine and other impurities. Much faulting occurs with the veins, and both the hanging and foot walls are generally fault planes. The serpentine is much broken in the neighborhood of the veins, the interstices being filled by smaller veins of magnesite.

On the foot wall of several of the veins extensive silicification has taken place, the serpentine being hardened through 2 or 3 feet. The veins are often brecciated and cemented with less pure material of yellowish color, while the original magnesite is a clear white. Frequently in the brecciated portions each fragment is covered by magnesite in radial crystals, forming a coating up to half an inch thick and varying in color from crystalline clearness to delicate green and yellowish green. Cracks in the serpentine are also filled with the same crystalline magnesite. This form is strikingly different from the ordinary magnesite, which in these deposits shows no crystal form to the unaided eye. In places crevices in the vein have a velvety black coating of pyrolusite (manganese dioxide), making the rock look as if it were coated with lampblack. A small amount of chromite has been found in the neighborhood, but not in paying quantities. An analysis of magnesite from this mine is given on the next page.

POPE VALLEY.

What is usually known as the Walters magnesite mine is located on the east side of Pope Valley, 22 miles northeast of Rutherford. The distance of the mine from the railroad makes hauling expensive, and the mine has never been worked on a large scale and has had no production for several years. A proposed electric road from San Francisco to Lake County will pass, if built, within 4 miles or less of the mine, in which case it will be in an excellent position to ship magnesite.

The deposits are situated in a serpentine hill, about 400 feet (barometric measurement) above the valley. They are composed of a large number of veins whose exposures vary in width from a fraction of an inch to 12 feet, and lie on both sides of a small ravine which forms an amphitheater, with an easy, straight southward grade to the valley, making an almost ideal place to work with an aerial tram.

The deposits are in three principal groups, two of which lie on the east side of the ravine and the other on the west. In the main group on the east side are three large veins of magnesite which can be definitely traced for distances of about 140, 250, and 230 feet respectively, with strikes of N. 28°, 30°, and 45° W. At their north end the western and eastern veins are but 30 feet apart, with the middle vein probably converging with the eastern one. The dip of the western vein is shown by a shallow shaft to be 50° E. The veins stand up boldly and can be seen from any part of the valley not hidden by hills. Longitudinal faults occur in both of the outer veins. Between the large ones are many smaller veins having a general parallelism to the main bodies. At its widest exposure the western vein is about 10 feet thick, of which about 5 feet on the foot wall are solid white magnesite, while the upper 5 feet (on the hanging-wall side) contain many inclusions of serpentine. The structure of the eastern vein is similar and in places the magnesite may be seen grading into the country rock. It is about 12 feet wide where exposed in a shallow crosscut. In the middle vein a width of 18 inches to 5 feet of clear white magnesite is exposed.

There has been some crushing of the magnesite and the broken particles have been cemented with yellowish, less pure material. Part of the magnesite has formed in yellowish botryoidal masses that are rather impure. Some crystalline magnesite, similar to that of Chiles Valley, is found in the crevices. But a small amount has been mined, and that was simply broken from the exposed faces of the veins.

A second group of veins with a more northerly strike occurs 100 feet or more above the veins just described. The veins forming this second group are smaller, running from 2 inches to 2 feet in width, and the larger ones are impure. There are also many scattered veins in the intervening space.

On the west side of the ravine is a third group of veins 200 to 250 feet from those first described, with a strike between north and northwest. The largest is a vein 4 to 6 feet wide and seven others from 1 to 2 feet wide occur within a space of 125 feet. All are of excellent quality. It would seem possible to blast out the whole of the rock through this distance and hand pick it, should the deposits again be worked.

PORTERVILLE DEPOSITS.

The Willamette Pulp and Paper Company is working a large group of magnesite veins 4 miles northeast of Porterville, in the outer range of foothills of the Sierra Nevada. The veins occur in a brown serpentine, derived from peridotite and having an apparent bedding structure. The serpentine forms part of a metamorphic complex of amphibolite-schist, serpentine, and other magnesian rocks, some talcose and mica bearing, and a small amount of fine-grained quartzite. The rocks have a general northerly strike, with a high (60°) easterly dip. They are cut off by a granitic mass on the south, a few hundred feet from the deposits, and several granitic dikes cut the serpentine and other rocks. Basic dikes of several varieties cut both the country rock and the veins and are occasionally squeezed to a schist.

Faulting is frequent, but the serpentine is not divided into the small irregular blocks usual in the Coast Range and many other serpentines, due to the swelling of the rock as it changes its chemical form. Internal movement is evident and the magnesite is invariably crushed in the larger veins. In one vertical 2-foot vein a couple of hundred feet southeast of the kiln the magnesite has been so squeezed that it has taken a modified cone-in-cone structure and is left in irregular fragments whose sides are covered with abrasion lines, the whole looking as if at the time of crushing it had been in a semiplastic state. In other veins the planes along which the magnesite has moved on itself are smooth and shaped so as to somewhat resemble the curve of a highly arched shell. Along these planes is often a bright-red stain of iron oxide, although the surrounding magnesite is pure white. At the north end of the deposits are several "blanket" or flat veins. The largest one is practically horizontal in the middle part and somewhat uptilted at both ends. It extends through the hill a distance of 362 feet, and is probably twice as long, and from 2 to 4 or more feet thick. A basic dike flattens and spreads under a large part of the vein in a thin sheet 1 to 2 feet thick; then, breaking through, it overlies the remainder of the vein.

There is nothing to show that the vein has been tilted from a more upright position to its present place and it was evidently formed as it lies, flat and cutting across the vertical structure of the serpentine. This is accounted for by supposing that there was a slow movement in the rocks along this plane at the time of the vein's deposition, the magnesite filling uneven, open spaces along the horizontal fault, and that when there was another movement these depositions would hold the mass apart and make room for contiguous deposits. The crushed condition of the whole mass and inclusions of serpentine in lines approximately parallel to the sides of the vein give this hypothesis some color. The other "blanket" veins lie at rather low angles and will probably be found to run into this one. At the north end of the deposits is a stockwork of small veins 2 to 6 inches thick, and it is thought that it may pay to blast the whole mass and hand pick it.

With the exception of magnesite shipped to the Western Carbonic Acid Gas Company, of San Francisco, for making gas, all the magnesite mined here is burned before being shipped. Crude oil is used for fuel, and the magnesite is fed into the top of a kiln, gradually rising in temperature until it reaches the flame from the burners. It is then raised to a white heat and kept there for from twenty to twenty-five minutes, when it is withdrawn. Shipments are made from Hilo, a spur on the Southern Pacific Railroad, 1 mile north of Porterville.

Analyses of magnesite and magnesia.

	1.	2.	3.	4.	5.	6.	7.	8.
Silica (SiO_2)	0.10	0.50	1.10	3.30	2.48	[a]1.81	[a]6.68	[a]0.90
Iron oxide (Fe_2O_3)	.25	.30	.47	7.25	6.02	.08	15.10	.49
Alumina (Al_2O_3)	....	....	.76	.84	1.18			
Lime (CaO)	.62	.70	....	2.48	4.34	Trace.	....	1.49
Magnesia (MgO)	47.10	46.90	97.35	84.72	84.56	46.55	37.23	44.39
Carbon dioxide (CO_2)	51.98	51.60	....	....	....	51.25	40.98	50.06
Water and undetermined	....	....	.32	1.40	1.33	.32	....	2.57
	100.05	100.00	100.00	99.99	99.91	100.00	99.99	99.90

[a] Insoluble.

1, 2. Alameda claim, American Magnesite Company, 32 miles southeast of Livermore, Cal.
3-5. Same, calcined.
6. Chiles Valley.
7. Same, poor; not shipped.
8. Porterville.
Analyst, Nos. 1-5, unknown; 6-8, Abbot A. Hanks, 531 California street, San Francisco, Cal., October 1, 1903.

THE BURNING OF MAGNESITE.

Among men engaged in the burning of magnesite a difference of opinion has existed as to the temperature at which the carbon dioxide can be driven off. In recent experiments Herr Otto Brill[a] has determined this point, and made a number of interesting discoveries as to the behavior of magnesite when heated. His experiments were carried on with carefully prepared and purified materials, so that his results are not exactly analogous to those that would be obtained by using the raw natural material. He showed that, while calcium carbonate (as ordinary limestone) gives up all of its carbon dioxide at 825° C. (1,517° F.), when magnesium carbonate (magnesite) is burned it begins to give off carbon dioxide at about 235° C. (455° F.); little if any more carbon dioxide seems to be given off while the material is held at 255° C., but on raising the temperature the gas is again given off. Other such stages were marked at various points, and these were considered to show the successive formation and breaking up of various basic carbonates. The last of the carbon dioxide is given off at 510° C. (950° F.), a temperature much below that needed to burn lime. Herr Brill's table showing the different carbonates is given below. The fifth column, the reduction to the Fahrenheit measurement of temperature, is added by the writer of this paper.

Basic carbonates formed in burning magnesite.

	Calculated MgO.	Obtained. MgO.	Dissociation temperature.	
	Per cent.	*Per cent.*	*° C.*	*° F.*
$10MgO.9CO_2$	50.64	50.58	265	509
$9MgO.8CO_2$	50.79	50.98	295	563
$8MgO.7CO_2$	51.20	51.37	325	617
$7MgO.6CO_2$	51.51	51.69	340	644
$6MgO.5CO_2$	52.36	52.35	380	716
$5MgO.4CO_2$	53.41	53.03	405	761
$7MgO.CO_2$	86.53	86.31	510	950

The temperature at which magnesite gives up the last of its carbon dioxide, 510° C., is below a red heat, but the time required to drive off all of the gas is not given, and this, of course, would vary with the size of the material used. The important point, however, is that at this temperature all of the carbon dioxide may be driven off, so that, although higher heating will undoubtedly remove the gas more quickly, it ordinarily means a waste of fuel.

MANUFACTURE OF LIQUID CARBON DIOXIDE.

At the time of the writer's visit the Western Carbonic Acid Gas Company of San Francisco, with works across the bay at Sedan or Emeryville, was the only maunfacturer of carbonic-acid gas from magnesite, although one of the subsidiary companies of the American Magnesite Company was erecting a plant at East Oakland (Clinton).

The magnesite is burned in a kiln with one-tenth its weight of coke, and the gas is pumped into scrubbers, of which there are three, filled with broken limestone to counteract any sulphuric acid formed, and washed with sea water. The gas then passes to an absorption tower, where it comes in contact with a sprayed solution of potassium carbonate, by which it is absorbed. The "loaded solution" is then pumped into boilers, where it is raised to a temperature just below the boiling point of water. The solution gives up its gas and is sent back to the absorption tower, while the gas is pumped through cleansing tanks to a gasometer. It is then compressed in a three-step compressor to the liquid state and is shipped in steel cylinders holding 25 to 60 pounds. In this process the weight of gas obtained is about 50 per cent of the weight of the magnesite used. The gas is shipped all over the Pacific coast and the Southwestern States. It is used in refrigeration and in making soda water and other aerated beverages.

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[a] Ueber die Dissoziation der Karbonate der Erdalkalien und des Magnesiumkarbonates: Zeitschrift für Anorganische Chemie, Band 45, Heft 3, June, 1905, pp. 277-292.

This same company is preparing to make light magnesia alba, by the Pattinson process, to be used as an absorbent for nitroglycerin in the manufacture of dynamite. It is said to make a very superior absorbent for the best grades of dynamite.

THE LIME INDUSTRY OF KNOX COUNTY, ME.

By Edson S. Bastin.

DISTRIBUTION OF THE LIMESTONES.

The limestones of Maine which are utilized commercially in the production of lime are confined to Knox County. The limestone areas form, in general, long, narrow, somewhat irregular strips trending northeast and southwest and surrounded by quartz rocks and schists. The largest continuous area extends from Chickawaka Pond, 2 miles north of Rockland, in a southwesterly direction, somewhat over 5 miles, to Thomaston, where its southernmost exposures are seen in the yard of the State prison. In some places this belt has a width of nearly a mile, although all of the rock is not of commercial quality. The second largest deposit extends from the east shore of Rockport Harbor, near the Henry Cottage, northward to Lily Pond and thence assumes a more westerly trend; it takes in the Jacobs quarry on the trolley road between Rockport and Camden and extends to the west of this road for a little over a mile. After a short interruption the same belt appears again just west of Simontons Corners, where it includes the Eells quarry. (See fig. 13.) Next in commercial importance is the deposit occurring 2 miles northwest of the village of

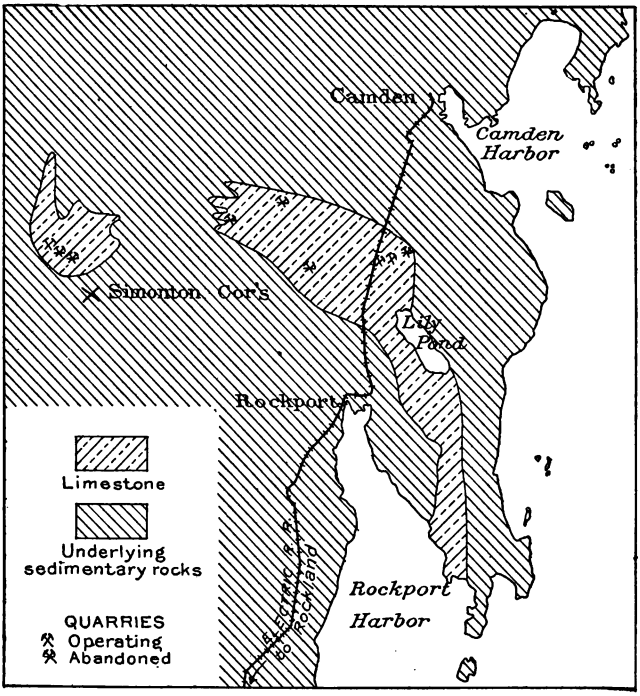

FIG. 13.—Map showing distribution of limestone and location of quarries in the vicinity of Rockport, Me.

Warren; this deposit was not mapped in detail, but enough was learned of it to show that it was relatively small and that its trend was similar to that of most of the other areas. Several narrow belts occur between the Warren deposits and Alford Lake, but none of these are now worked. Southwest of Rockland there are, as shown on the map forming fig. 14, several narrow belts nearly parallel to the main limestone belt. On the easternmost of these belts is located the pulp-rock quarry now being operated by Mr. S. P. Dunton for the McLoon & Stover Lime Company.

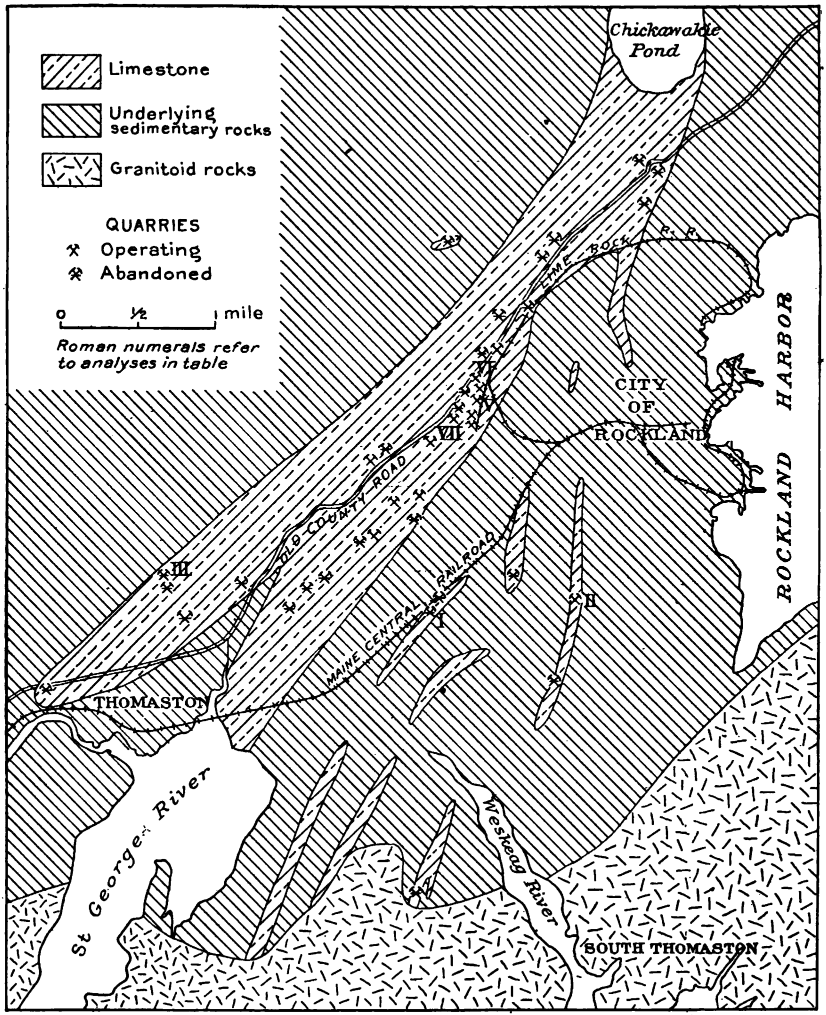

FIG. 14.—Map showing distribution of limestone and locations of quarries in the vicinity of Rockland and Thomaston, Me.

PRESENT UTILIZATION.

Within the district under consideration limestone is now quarried (1905) at nineteen quarries, operated by ten different companies and employing an average of 250 quarrymen. The great bulk of the rock is burned for common lime, but a small amount is shipped unburned for use in pulp mills or as flux,[a] and some is used in the production of a hydrated lime, to be discussed later more fully. The rock is not suitable for building purposes. The production in this region of common lime, hydrated lime, and limestone for pulp and flux purposes since the year 1898 is given in the following table:

Production of lime, etc., in Knox County.[b]

Year.	Common lime.	Hydrated.	Lime for pulp-making purposes (mainly magnesian).[c]	Limestone for flux and pulp-making purposes.
	Casks.[d]	*Tons.*	*Casks.*[d]	*Casks.*[e]
1898	1,610,178		(f)	(f)
1899	1,939,427		(f)	(f)
1900	1,728,134		(f)	(f)
1901	1,962,717		94,133	(f)
1902	1,589,982		78,157	(f)
1903	1,817,787	10,000	72,001	(f)
1904	1.792,559	12,500	52,909	21,000

[b] Compiled from records of lime inspectors at the various ports and from the records of private companies.
[c] All from quarries at West Warren.
[d] Of 200 pounds.
[e] Of 400 pounds.
[f] Statistics not available.

About two-thirds of the common lime produced goes to the New York market, where for many years it has had the highest reputation. Nearly all of this is shipped by water, the largest of the companies maintaining a fleet of six barges, each capable of carrying 15,000 casks (200 pounds each) of lime and of bringing on the return voyage 1,500 tons of coal. The remainder of the product goes to Boston and other New England markets. In spite of the fact that freight rates are lower by rail, most of the lime shipped to Boston goes by water, as the Boston building contractors have good docking facilities but in few cases have railroad yards. For the rest of New England the shipments are usually by rail. From one-fourth to one-third of the lime is of finishing grade.

Of recent years a process has been taken up by the Rockland-Rockport Lime Company which has not only proved a great success here and elsewhere, but which seems to point out an important line of future development in the lime industry. This process consists in a complete hydration of the lime before it is placed on the market. It has been carried on successfully in other parts of the country under a variety of patents, the product being variously known as "new-process lime," "hydrated lime," "limoid," etc. The Rockland product goes under the name of "prepared pure white lime." While differing in details, the various processes are identical in principle. The lime after burning is crushed or ground until no lumps larger than 1 inch in size remain. It is then transferred to a mixer, where it is thoroughly mixed with about 25 per cent of its weight of water, the chemical change produced being represented by the equation—

$$CaO+H_2O=Ca\ (OH)_2$$

Lime+water=lime hydrate.

A description of the effects produced by this hydration and of the subsequent steps in the process of manufacture may be quoted from one of the prospectuses of the Rockland-Rockport Lime Company. The lime "undergoes a radical change, its heating and expanding qualities being entirely removed; it is then conveyed to bins where it is allowed to age, the same result being obtained as when slaking lime several months before it is used; it is then bolted to the varying degrees of fineness according to the different purposes for which it is used and drawn into bags or barrels for the market." This process of manufacture has several decided advantages over the ordinary process: (1) Crushed and crumbled lime can be used in this way which can not be barreled for shipment as "lump" lime, although its quality may be equally good; (2) coarse-grained limestone which does not retain the lump well on burning can be utilized in this process; (3) the hydrated lime "will not absorb moisture, in other words it will not air slake, hence will keep in good condition until used;" this fact much decreases the risk in shipment by water and leads to a proportional reduction in insurance rates; lime thus prepared may be shipped in bulk and for long distances, the Rockland-Rockport Lime Company having recently made shipments to Panama for disinfecting purposes; (4) "as the lime has been reduced to a powder, there is absolutely no liability of its pitting on the walls." Finally, it is believed that this process of manufacture is not greatly more expensive than the manufacture of common lime; the machinery needed is not complex; savings in the matter of materials utilized and of insurance have already been mentioned; and there is an additional saving when shipments are made in cloth bags. These are much cheaper than casks, which cost 16 to 17 cents each, and being light can be shipped back after emptying and used again and again.

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[a] Only a very small amount is used for flux.

GENERAL CHARACTER AND MODE OF OCCURRENCE.

The limestones of Knox County have all been completely recrystallized since their original deposition. They are now virtually marbles, although either too coarse, too dark colored, or too much fractured to be used for ornamental or building purposes. In color the rock used varies from dark purplish-gray to pure white, the commonest colors being light gray and dark blue-gray. In the Rockland quarries a variety showing alternate bands of grayish white and dark blue-gray is very common. In the bulk of the rock quarried the grains are under one-sixteenth inch in diameter, and in some occurrences they are so small as to be unrecognizable with the naked eye, but in other cases may reach a diameter of one-fourth of an inch.

The general form of the limestone belts has already been described, and is shown on figs. 13 and 14; it remains now to discuss briefly the structural relations of which this distribution is an expression. All the sedimentary rocks of this region were deposited in a nearly horizontal position, as muds, sands, and marls, upon the ocean bottom, where they gradually consolidated to form, respectively, shales, sandstones, and limestones. At a later period these sediments were thrown into a series of long, narrow folds commonly trending 20° to 30° east of north, or about parallel to the general trend of this part of the coast. As in most regions where folding of this kind has taken place, the larger folds were themselves thrown into a series of smaller folds, which trend parallel to the larger ones—a relation which may be illustrated by the curved surface of a crimping iron, which is itself fluted with minor folds.

The minor folds in this region are closely compressed, so much so that when seen in cross section opposite sides of a fold are often nearly parallel. As a result of this, the beds are now for the most part steeply inclined, as may be observed in the easternmost series of quarries of the Rockland-Rockport Lime Company, west of Rockland. Here the bedding is indicated by a very distinct banding, which is almost vertical. The relations are complicated by the presence of cross folds, which trend about at right angles to the main folds. They influence the form of the limestone belts in various ways; for example, the narrowing of the Rockport belt about one-half mile south of Lily Pond is due to a cross fold, which in this case is an up fold or anticline, while in the region southwest of Rockland the interrupted character of the narrow limestone belts is also due to the presence of cross folds. Within the main limestone belt the crookedness observed in the trend of some of the limestone "veins" is due to folds which cross the main folds diagonally.

During this process of severe folding, the various types of sediments were intensely altered, the shales being changed to schists, the sandstones to quartzite, and the limestones to marble. The schists are well exposed at Bear Hill, Ingrahams Hill, and many other places, and are commonly known as "land ledge." The muds from which they were derived were deposited on the ocean bottom somewhat earlier than the limestones, which in most places they immediately underlie. In the region southwest of Rockland, however, there is a local development between the schists and the limestone of a considerable thickness of quartzite and a thin bed of talcose limestone. Fig. 15, which shows a section from northwest to southeast across the limestone belts southwest of Rockland, is intended to illustrate the general relations outlined above; it is not drawn to scale and is purely diagrammatic, the folding being in places even closer than shown. The sedimentary rocks underlying the limestone are represented by A in the figure, the locally developed quartzite and talcose limestone beds not being separately shown. Among the limestones several varieties are indicated, B=magnesian limestone or dolomite, C=the so-called "hard rock" of the quarrymen, D=impure limestone, and E=the "soft rock" of the quarrymen. These limestones form a broad down fold (synclinorium), which is itself divided into a number of smaller folds, both up folds (anticlines) and down folds (synclines). A comparison of this cross section with fig. 14 shows that, considered as a whole, the limestone occurs as a broad trough made up of numerous smaller folds. The main large fold is not perfectly symmetrical, its western side being relatively steep; as a result, the limestone terminates abruptly on the west. To the southeast, however, we have a number of small outlying limestone troughs (see fig. 14), which represent the minor foldings of the main trough and show that its eastern side has a much gentler slope. One of these outlying troughs is shown in fig. 15 at B′.

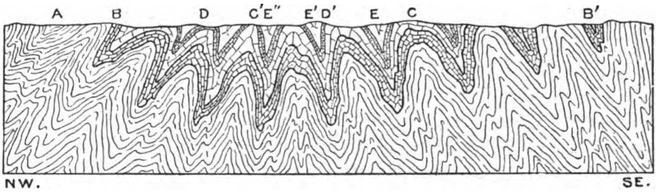

FIG. 15.—Diagrammatic geologic section across the principal limestone belt southwest of Rockland, Me.

The position of the magnesian limestone at the base of the limestone series is definitely determined by field studies, but the relative position and thickness of the "hard rock," the impure limestone, and the "soft rock" are not known, the relations having been obscured by the folding and its attendant alteration of the rocks. The reader is therefore especially cautioned against drawing any inferences from the diagram in regard to the sequence or relative thickness of these three types of rock.

MAGNESIAN LIMESTONE OR DOLOMITE.

The presence of magnesian limestone below the other varieties is shown particularly from a study of the limestone belts lying southeast of the large Rockland belt (see fig. 14). These outlying belts are usually only 100 to 200 feet in width and manifestly can represent only the lower part of the limestone series, as is brought out in fig. 15 at B′. In each of these outlying areas the bulk of the rock is found to be a magnesian limestone, a characteristic which may be recognized in the field from the fact that the rock effervesces feebly or not at all when dilute muriatic acid is applied. This rock is usually light gray to pure white in color and very fine grained. It has been quarried at a number of places and is usually used for pulp purposes. At the Gay farm, about 2 miles southwest of Rockland along the railroad, one of these small troughs of magnesian limestone was formerly worked by the Rockland-Rockport Lime Company. Analysis No. I of the table (p. —) is of a limestone from this quarry. The rock was of uneven grain and apt to be high in silica and silicates. The quarry was abandoned, although the supply along the trend of the deposit was by no means exhausted.

The quarry 1 mile southwest of Rockland, on the east side of "the Marsh," now being operated by Mr. S. P. Dunton for the McLoon & Stover Lime Company, is located on the southeasternmost of these outlying strips of magnesian limestone. It was opened in June, 1905, and the output to November 17, 1905, was 6,000 casks. The rock is similar in appearance to that from the Gay Farm quarry. At present it is all burned for pulp-making purposes. Its analysis is No. II of the table (p. —) and shows nearly 43 per cent of magnesia. A quarry formerly operated by Mr. Geo. W. Barry, on the Butler farm, about half a mile south of the quarry above mentioned, is located on the same strip of limestone; the rock is identical in appearance and gives an almost identical analysis. At the Dunton quarry a considerable amount of rock is rendered worthless because of the abundant development of talc (a silicate of magnesium), but it remains to be seen whether the quantity is sufficient to prohibit profitable development.

In general, the exploitation of the isolated strips of limestone southeast of the main belt should proceed in a most cautious manner, and the following facts should be kept constantly in mind: First, the rock is a magnesian limestone which at present finds a market only with the pulp mills; second, a certain proportion of the rock is likely to be talcose, and therefore commercially valueless; third, the amount of rock is relatively small, the belts seldom exceeding 200 feet in width and often being less. They may be expected to narrow rather than to widen with depth. The installation of expensive machinery is therefore not warranted.

Within the broad Thomaston-Rockland limestone belt magnesian limestone was found only at one locality. Its absence throughout most of the belt is readily understood from the diagram (fig. 15); it is buried beneath the other members of the limestone series. Theoretically, as is seen from the diagram, it should come to the surface on the eastern border of the belt, but this border is covered up by clays throughout its whole length. On the western border of the limestone area, at the locality marked III on the map, we do however, find a magnesian rock. This is at the Levensaler quarry about 1 mile north of Thomaston. Its approximate situation with respect to the rest of the limestone belt is indicated by the letter B in fig. 15. The analysis is No. III of the table (p. —) and shows 21 per cent of magnesia. Besides carrying this lower magnesia percentage the rock is coarser and of a bluer color than that of the outlying areas east of the main belt.

The most important deposits commercially of magnesian rock are those 2 miles northwest of the village of Warren. Here there is a down-folded belt of limestone similar in origin to the magnesian belts southwest of Rockland, but considerably wider and probably deeper. The principal difference is in the fact that the schists which surround (underlie) the limestone have been permeated with granite, dikes of which occasionally cut the limestone. The presence of this granite has resulted in a greater amount of recrystallization and purification of the limestone than in the Rockland region, but it has also resulted in the development, near the granite, of silicate minerals in good-sized crystals, which render some of the rock worthless. For years this rock has found a ready market for pulp-mill use, about five-sixths being shipped as lime and one-sixth as raw rock.

During the past year the Warren Company has placed on the market about 20,000 casks of this magnesian lime for building purposes. On the relative merits of the calcium and magnesian limes for building purposes the following may be quoted from Eckel:[a]

> The relative merits of these two classes have been frequently discussed in the text-books and technical journals and are still subjects of controversy. The facts of the case, however, seem to be simple enough and may be summarized as follows:
>
> High-calcium limes slake rapidly on the addition of water and evolve much heat during slaking. They also expand greatly, giving a large bulk of slaked lime. Magnesian limes slake very slowly and evolve very little heat during the process. Their expansion is also less, so that, taking equal weights they give less bulk of slaked lime.
>
> Owing to the slowness and coolness with which the magnesian limes slake, there is some danger that the average mortar mixer will not give them sufficient time to slake thoroughly. Owing to the fact that they make less bulk of slaked product than do high-calcium limes, the average contractor or builder thinks they are too expensive; but, on the other hand, they are very much stronger in long-time tests than the high-calcium limes, and will therefore carry much more sand.

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[a] Eckel, E. C., Cements, Limes, and Plasters, 1905, p. 115.

On the whole, the shipment of magnesian limes for building purposes is to be encouraged, but it is a question whether a product of more merit can not be secured by the hydration of this lime before it is placed upon the market. The process of hydration would not be greatly slower than in the case of calcium limes and the danger from imperfect slaking at the hands of the mortar mixer would be completely avoided. The result should be a lime which is superior in strength to the calcium limes.

Recently there has been considerable complaint from pulp-mill operators because there has often been much dirt mixed with the raw magnesia rock and with the magnesian lime which was shipped to them, and some custom has been lost for this reason. Owing to the clay covering which usually overlies the limestone here, it is difficult to keep the rock perfectly clean. Probably this trouble could be remedied in part by keeping the stripping of the clays further in advance of the quarrying, but it is worth considering whether the rock could not be washed before shipment or burning at little or no extra expense by utilizing the water which is pumped from the quarry, but which usually serves no useful purpose.

THE MAIN ROCKLAND-THOMASTON BELT.

The diagram (fig. 15) brings out certain features of importance in regard to the distribution of the different kinds of limestone within the main belt. These may be enumerated as follows, always bearing in mind the caution already given, that the diagram is not intended to show actual thicknesses or sequence, but to bring out correctly the principles involved.

(1) *Repetition of beds.*—The character of the folding is such that the same bed is likely to be repeated several times in the width of the belt. Thus the bed E (fig. 15) appears again at E′ and E″, and the bed C is repeated at C′. As a result we may have within the broad limestone area several nearly parallel belts of almost identical rock, separated by belts of poor rock or of good rock of a different kind. This principle finds an immediate application in the prospecting for new deposits. This search should be conducted by test troughs or ditches dug through the surface clays and gravels at a right angle to the general trend of the limestone belts. Such prospect ditches are likely to disclose, beyond the walls of poor rock which bound the pits now worked, a repetition of the same profitable bed or the presence of a bed of good rock of a different kind—that is, "hard" instead of "soft" rock, or vice versa.

(2) *Width of surface outcrops.*—The surface width of the bands of "hard rock," "soft rock," and impure limestone depend not only on the original thickness of these various beds, but also on the character of the folding and the position of the present surface with respect to these folds. Thus the "hard rock" as it outcrops at C is a broad band, while at C′ its outcrop is narrow. The same is true of the impure limestone, which, as represented at D, has a broad outcrop, but at D′ a very narrow one.

(3) *Depth of the folds.*—As already stated, the folds which are developed in these rocks are more compressed even than is shown in the diagram. Their depth is greater than their width; in many cases it is probably two or three times as great. As a consequence it may be expected that in most cases a "vein" of a valuable rock can be worked to a depth which is at least equal to its width and which may be twice its width. In only a few cases, as at locality C (fig. 15), is the depth likely to be less than the surface width.

(4) *Prospecting outside the limestone area.*—In the past considerable time and money has been expended in sinking drill holes and prospecting in other ways for limestone in the schist ("land ledge") areas outside the limestone belts. Since the schists lie beneath the limestones, it is manifestly useless to expect to find limestone by drilling through the schists. In nearly every case, if limestone is present at all, it will be present at the surface.[a]

The field studies within this region indicate that the supply of valuable rock does not remotely approach exhaustion, and that intelligent prospecting following the methods already outlined will disclose large deposits whose presence is not now suspected. The successful utilization of these deposits will depend very largely on the depth of clay which must be stripped off before the limestone is exposed; in general this thickness will be greater than in the case of most of the "veins" now worked. In prospecting, the thickness of the covering material can be tested readily with an auger before digging is attempted; if too great to warrant its removal the prospect may be abandoned in favor of a locality where the covering is not so deep. In general this thickness is least in the highlands and greatest in the lowlands; hence the former offer the most promising field for prospecting.

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[a] Some limestone does occur locally below the schists, but it is older than the limestone here discussed and is not of economic importance.

PORTLAND CEMENT.

The possibility of utilizing the clays which are abundantly developed in the Rockland region and which in some places directly overlie the limestone, in the manufacture of Portland cement has already received some attention from quarry operators in this region. The matter is rather fully discussed by the writer in another part of this bulletin, in an article on "Clays of the Penobscot Bay region" (pp. 428–431). In this article the abundance and availability of the clays are brought out. It may be stated here, however, that the clays have a composition which suits them to this purpose, and that if the clays obtained from stripping could be utilized in this way limestone beds could be profitably worked, which otherwise it would not pay to uncover. For cement-making purposes in the utilization of the clay the magnesian limestones are not serviceable, for when mixed with clay they do not form so strong a cement as the calcium limes.

Analyses of limestone and limes from Knox County, Me.

	I.	II.	III.	IV.	V.	VI.	VII.
Carbonate of lime	....	53.13	74.36	53.52	....	....	98.17
Carbonate of magnesium	....	42.94	21.62	45.13	....	....	.09
Calcium oxide	55.10	....	....	....	96.31	85.51	....
Magnesium oxide	38.70	....	....	....	1.13	9.25	....
Silica and insoluble matter	4.59	2.87	1.85	.90	1.42	2.74	1.08
Iron and alumina	1.61	1.06	1.04		1.08	1.61	.15
	100.00	100.00	98.87	[a]100.00	99.94	[b]100.00	[c]99.77

[a] Total includes moisture, etc., 0.45 per cent.
[b] Total includes 0.89 per cent loss on ignition.
[c] Total includes 0.28 per cent of organic matter.

I. Magnesian lime from Gay Farm quarry, 2 miles southwest of Rockland along the railroad. R. S. Edwards, analyst.

II. Magnesian limestone from quarry operated by S. P. Dunton, 1 mile southwest of Rockland. Specimen taken at depth of 18 feet. F. C. Robinson, analyst, Brunswick, Me.

III. Magnesian limestone from Levensaler quarry, 1 mile north of Thomaston. Deficiency in total may indicate error in figures.

IV. Magnesian limestone from quarries at West Warren. S. P. Sharples, analyst, Boston, Mass.

V. "Soft-rock" lime from eastern pit of Rockland-Rockport Lime Company, near Rockland. R. S. Edwards, analyst.

VI. "Hard-rock" lime from Fred Ulmer "hard-rock" quarry, west of Rockland. R. S. Edwards, analyst.

VII. "Soft-rock" from McNamara quarry, Rockland. F. C. Robinson, analyst, Brunswick, Me.

GYPSUM AND PLASTERS.

GYPSUM OF THE UNCOMPAHGRE REGION, COLORADO.

By C. E. Siebenthal.

Location.—The gypsum measures herein described are located on the west side of the Grand Canyon of Gunnison River, partly in Delta County and partly in Montrose County, Colo., as shown on the accompanying sketch map (fig. 16). The eastward extension of the measures across the canyon, in all probability, likewise contains extensive deposits of gypsum, but as they are accessible only with much difficulty from the west side of the river they were not visited, though their position has been indicated on the map.

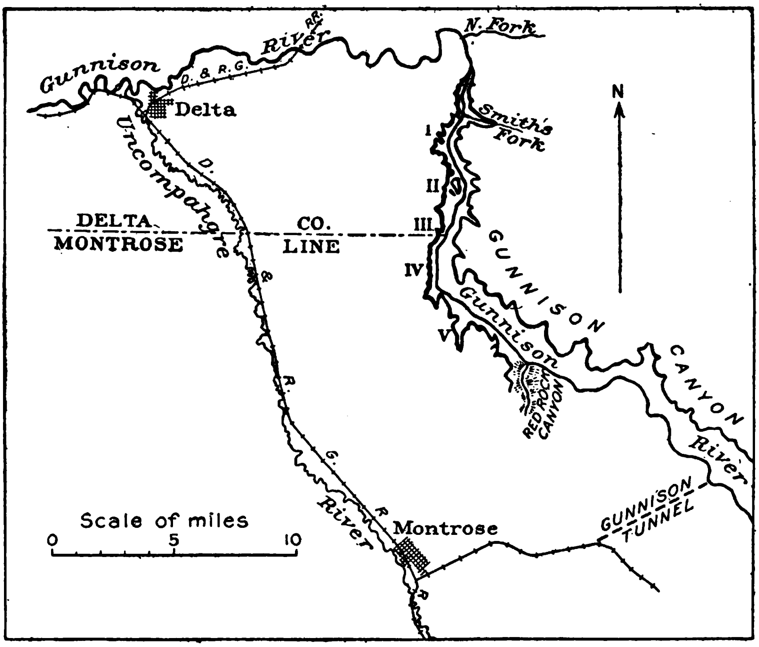

FIG. 16.—Gypsum measures of the Uncompahgre region.

Structure.—From the intake of the Gunnison tunnel the river flows northwestward for 18 miles and then due north for 12 miles, thus skirting the southwest and west edges of the Mesa Inclinada. This course approximately coincides with the asymmetric anticline which changes the gentle northeast dip of the mesa to a steeper southwest dip in the territory bordering the 18 miles of canyon on the southwest and to a west dip in the lower 12 miles of its course. The Mesa Inclinada is a dip or structural slope of between 2° and 3°, the surface of which is formed by the "Dakota" sandstone. The same sandstone, for the most part, forms the crest of the ridge which borders the canyon on the west. The river has cut through the sandstone and underlying formations and, in the south part of the area, has cut 2,500 feet into the crystalline complex. Near the north edge of the area the northward slope carries the schists below drainage.

Geology.—Overlying the schists is a bed of massive, fine-grained sandstone of a pinkish to yellowish or salmon color, weathering with characteristic rounded outlines, concave and convex. The thickness of this bed in the southern part of the area is about 100 feet, thinning to the northward to about 50 feet. The upper part becomes flaggy, then shaly, and passes upward into the gypsum measures, which are in turn succeeded, either directly or with an interval of 30 to 40 feet of shales and sandstones, by 40 to 50 feet of blue calcareous shale, with interbedded flaggy, drab limestones, containing a few fresh-water fossils. This is followed in turn by 400 feet of variegated, but predominantly reddish shales, with interbedded red and buff sandstones. The so-called "Dakota" comes next and completes the section of the canyon wall. It consists at the bottom of from 40 to 60 feet of massive coarse-grained, buff sandstone, with sheets and strata of conglomerate, the pebbles averaging one-half inch in diameter and consisting of jaspers and cherts of various colors. The upper member of the formation consists of similar sandstones, usually not so thick, less massive, and with less conglomerate. Between the sandstone members is a series of interbedded dark shales and buff sandstones, with here and there thin beds of coal. The thickness of the whole "Dakota" series is about 200 feet.

Gypsum measures.—With an average thickness of 110 feet and a maximum thickness of 150 feet, gypsum measures outcrop in the west wall of Gunnison Canyon uninterruptedly from a point below the mouth of Smiths Fork southward to Red Rock Canyon, a distance of 20 miles. Immediately west of Red Rock Canyon they cross over the divide between Gunnison and Uncompahgre rivers and plunge sharply beneath the rocks of the Uncompahgre Valley. From this point southeastward along the faulted anticline which marks the west limit of Vernal Mesa the gypsum measures are either wanting or concealed by débris, except at two points along the Tunnel road in sec. 17, T. 49 N., R. 7 W., where thin beds of gypsum appear.

The stratigraphy of the gypsum measures is well shown in the following sections, taken at different points along the west wall of the canyon:

Sections showing gypsum measures in Gunnison Canyon, Colorado.

I.

	Feet.
Shale and sandstone; gypsum in gash veins and lumps constitutes one-third of the whole	30
Solid granular white gypsum	10
Solid gypsum, with some shale near top	30
Red to green clay, gypsiferous	14
Solid granular gypsum	25
Concealed, shale at top	20
Solid white gypsum	4

II.

Gypsiferous sandstone	11
Nearly solid gypsum, shale one-fifth of whole, some lumps of limestone	60
Bluish gypsiferous shale; bands and gashes of gypsum	36
Sandstone	6
Solid gypsum	4
Arenaceous gypsum	4
Reddish gypsiferous shale	13
Solid gypsum	8

III.

Clay and gypsum; gypsum perhaps one-third of whole	44
Shale and arenaceous gypsum	48
White gypsum rock	5

IV.

	Feet.
Blue gypsiferous shale	6
White massive sandstone	5
Sandstone and shale	8
Shale with gypsum in plates and gash veins	4
Solid white gypsum	4
Gypsiferous shale	7
Solid gypsum	1
Gypsiferous sandstone	2
Shale	4
Gypsiferous sandstone	2
Shale	2
White granular gypsum	2
Shale	8
Gypsiferous sandstone	18
Red shale	12
Soft white gypsum	8
Gypsiferous sandstone and shale	40

V.

Shale and sandstone, with gypsum in beds	6
Gypsiferous sandstone	40
Pinkish to red sandstone	22
Gypsiferous sandstone	4
Arenaceous shale, gypsum	22
Solid white gypsum	8
Arenaceous shale, gypsiferous	35

Section I is under the big hill at the west bend of the river, 2 miles southwest of the mouth of Smiths Fork.

Section II is at the big hill 2 miles south of Section I.

Section III is near the sharp eastward bend of the river in sec. 23, T. 51 N., R. 9 W., about 3 miles south of Section II.

Section IV is at the low gap 2 miles south of Section III.

Section V is 3 miles south of Section IV and 2 miles due east of Devils Elbow.

In the foregoing sections, where solid gypsum appears, it was seen at the surface, but the gypsiferous shales and sandstones disintegrate very easily, and the surface is covered by a deep mantle of loose sand and clay which undoubtedly conceals many beds of rock gypsum.

The great variability of the gypsum measures from place to place is well shown in the sections, the only persistent member being the bed of gypsum from 4 to 8 feet in thickness which appears at or near the base of each section.

Along that portion of the outcrop covered by the sections given above, the surface is so steep that mining would be necessary from the start. The most easily accessible gypsum is that at the low gap where Section IV was taken. The top of the gypsum measures is about 150 feet below the gap, which may be reached by an easy grade from the county road to the west.

Between Red Rock Canyon and the locality of Section V there is a hill sloping gently westward, the surface of which is a dip slope composed in part of the gypsum measures. In this region in places the gypsum beds lie near enough to the surface to strip, thus saving the expense of mining, but on the other hand they are a thousand feet higher than the deposit at the gap and the construction of many miles of road would be necessary to reach them.

GYPSUM DEPOSITS OF THE LARAMIE DISTRICT, WYOMING.

By C. E. SIEBENTHAL.

Introduction.—The gypsum deposits of the district are of two varieties—earthy gypsum or gypsite, and rock gypsum. The mill of the Consolidated Plaster Company, at Red Buttes, making both plaster of Paris and cement plaster, uses rock gypsum with a smaller amount of gypsite, while the plant of the Acme Cement Plaster Company, near Laramie, works the gypsite exclusively.

OCCURRENCES OF ROCK GYPSUM.

Red Mountain.—The heaviest developments of gypsum rock in the district are found along the foot of the north slope of Red Mountain, in the extreme southwest corner of the Laramie quadrangle, in T. 12 N., R. 76 W., just north of the Wyoming-Colorado line. The gypsum measures first appear from beneath the Tertiary near the middle of the west side of sec. 7 and, winding in and out around the foothills of Red Mountain, take in the main an east-west line through secs. 8, 9, and 10, pass out at the northeast corner of the latter, bend to the north, swing sharply westward through the middle of sec. 3, and turn northward again near the middle of sec. 4, the gypsum here becoming too thin to be of importance. The base of the gypsum beds throughout this region is marked by a bed of limestone a foot or more in thickness, which is nearly everywhere crowded with fossils, mostly, however, individuals of a few species. These have been determined to be of Upper Carboniferous age. A section of the gypsum measures, showing the maximum development in this vicinity, is as follows, taken from the top of the beds on the north foot of Red Mountain, in sec. 9, down to the fossil bed.

Section of gypsum measures at the base of Red Mountain, on the north side.

	Feet.
Red gypsum rock, nearly pure	6
Red shale	35
Gypsum	3
Red shale	10
Gypsum	4
Reddish shale	55
Banded gypsiferous rock (limestone)	5
Red sandy shale	88
Gypsum, massive	67
Fossiliferous limestone	1
	274

The heavy gypsum bed, ranging in thickness from 30 to 60 feet, extends nearly the whole length of the outcrop outlined above. The distance to Red Buttes, the nearest point on the railway, is about 25 miles.

Sportsman Lake.—A mile east of this lake, near the middle of the north side of sec. 7, T. 13 N., R. 73 W., there is an outcrop of gypsum. A small test pit sunk at this point developed 4 or 5 feet of pure rock gypsum, but whether this is the full thickness of the bed is not known. A curly, laminated, gypsiferous limestone crops out a quarter of a mile east of the gypsum and dips beneath it. This limestone is traceable as a slight ridge, east of north, to and beyond Forelle, passing a quarter of a mile east of Red Buttes station.

Red Buttes.—A mile south of Red Buttes station and a quarter of a mile east of the limestone ridge just described is a deposit of gypsum which has been worked by the Consolidated Plaster Company since 1890. These beds dip beneath the limestone and are therefore lower than the gypsum at Sportsman Lake. The quarry at present worked lies just east of the mill and shows a face of 15 feet of solid gypsum rock, which will be increased to probably 20 feet with farther progress into the hill. The quarry formerly worked lies northwest of the mill and shows a face of 8 or 10 feet. The dip of this bed would carry it 25 or 30 feet above the quarry now worked, showing the existence of two beds at this point. The upper bed was struck again near the point where the switch to the mill leaves the main line, but north or south of these occurrences the gypsum seems to thin out and disappear. An analysis of the gypsum from the quarry at the mill is as follows:

Analysis of gypsum from Red Buttes, Wyo.

[By D. O'Brine, Colorado Agricultural College.]

CaO	32.5
Al_2O_3	.3
Fe_2O_3	Trace.
SiO_2	.2
SO_3	46.3
H_2O	20.8
	100.1

Laramie and vicinity.—Gypsum is struck in the deep borings in Laramie at a depth of about 600 feet, but does not seem to be present at the outcrop of its horizon directly east of the city.

Five miles northeast of Laramie, in the SW. ¼ sec. 2, T. 16 N., R. 73 W., gypsum crops out at the north base of the small hill which enters near the middle of the south side of the section. Several test pits show a thickness of 9 or 10 feet of gypsum of an excellent quality.

OCCURRENCES OF GYPSITE.

Several valuable deposits of gypsum earth, or gypsite, resulting from the disintegration and transportation of rock gypsum, are found in the Laramie quadrangle. Some of these have been carefully bored and tested by parties interested in their location, while others have been located by their effect on the vegetation growing over them.

Laramie.—One of the chief deposits of gypsite is the one worked by the Acme Cement Plaster Company, just south of the city of Laramie. The deposit covers almost the whole of sec. 4 and has a depth of 9 feet where worked. The gypsite is in a finely divided state and goes directly to the calcining kettles without grinding or screening. The accidental impurities of deposition, such as sand, clay, and limestone, comprise about one-fifth of the whole, but do not interfere with its use for cement plaster. No plaster of Paris is made at this mill.

Other smaller deposits in the vicinity of Laramie are southeast of the fair grounds, across Spring Creek, and a mile northeast of Laramie, in the SE. ¼ sec. 28, T. 16 N., R. 73 W.

Other deposits.—Another larger deposit owned by the Acme Cement Plaster Company occupies almost all of sec. 4, T. 16 N., R. 73 W., lying east of the county road and overlapping the western part of sec. 3.

A deposit lies along Soldier Creek for 1 mile below and 2 miles above the site of old Fort Saunders.

A small deposit occurs in the valley of Harney Creek in the NE. ¼ sec. 21, T. 14 N., R. 73 W., a mile southeast of Red Buttes.

Another small deposit at Red Buttes, lying just west of the mill and having a depth of 5 or 6 feet, is worked by the Consolidated Plaster Company. Selected rock gypsum is used in the manufacture of plaster of Paris. The rejected rock is mixed with gypsite to make cement plaster.

An extensive bed of gypsite occupies the lower 2 miles of the valley of Willow Creek to its junction with Lone Tree Creek and extends 2 miles below the junction.

Another gypsite deposit occupies portions of secs. 33 and 34, T. 14 N., R. 74 W.

SURVEY PUBLICATIONS ON GYPSUM, SALT, BORAX, AND SODA.

The more important publications of the United States Geological Survey on the natural lime, sodium, and potassium salts included in this group are the following:

Adams, G. I., and others. Gypsum deposits of the United States. Bulletin No. 223. 123 pp. 1904.

Boutwell, J. M. Rock gypsum at Nephi, Utah. In Bulletin No. 225, pp. 483–487. 1904.

Campbell, M. R. Reconnaissance of the borax deposits of Death Valley and Mohave Desert. Bulletin No. 200. 23 pp. 1902.

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Packard, R. L. Natural sodium salts. In Mineral Resources U. S. for 1893, pp. 728–738. 1894.

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CLAYS.

CLAYS OF GARLAND COUNTY, ARK.

By Edwin C. Eckel.

General statement.—During the fall of 1905 the writer was detailed, at the request of the Secretary of the Interior, to examine the clays of the Hot Springs Reservation, Ark., and report on the commercial value of such deposits as could be found. In the course of the few days devoted to this work several clay deposits in Garland County, outside the limits of the reservation, were visited and sampled. The following paper is a summary of the principal features brought out by this work.

As the area covered by the Hot Springs Reservation lies entirely outside of the Cretaceous and Tertiary portion of Arkansas, the clays to be found there represent but two types: (1) Paleozoic shales, and (2) recent river and stream deposits. The latter group includes a few small clay beds which in places have been worked on a small scale for the manufacture of common red brick of poor grade. The Paleozoic shales, however, by their leaching and decay in place form a series of light-colored siliceous clays of more importance.

The area within the reservation was examined with some care, and several developed clay properties in other parts of Hot Springs County were visited for comparison. The localities and separate deposits are first described, after which the economic features of the matter are summarized.

Description of clay deposits.—On the southeast side of Hot Springs Mountain, near the road crossing its crest, a series of light-colored clays is exposed. The section shows 6 to 10 feet of these clays, mostly light-gray in color, but with occasional thin reddish bands. The clays are quite free from coarse sand or grit. Their strike and dip are very variable, but a fair average would probably be N. 70° W. and 25° S.

Samples were collected from this locality and analyzed in the Survey laboratory by George Steiger, with the following results:

Analysis of clays from Hot Springs Mountain.

Silica	73.07
Alumina	16.40
Titanic oxide	1.09
Iron oxide	1.12
Lime	.25
Magnesia	.64
Soda	.26
Potash	2.75
Combined water	4.46
Moisture	.36

Across the divide between Hot Springs Mountain and North Mountain a similar series of clays is exposed near the northeast corner of the reservation. At this point 8 feet of gray clay is shown, with no reddish bands, but containing considerable fine sand. Samples collected from this locality and analyzed by George Steiger gave the following results:

Analysis of clays from North Mountain.

Silica	70.31
Alumina	17.27
Titanic oxide	1.00
Iron oxide	1.85
Lime	.23
Magnesia	.91
Soda	.26
Potash	3.51
Combined water	4.36
Moisture	.88

On the south slope of West Mountain, clay beds are exposed at several points. These clays are of the same general character as those shown on Hot Springs Mountain and North Mountain. At the best exposure 5 or 6 feet of gray and red mottled clays are seen. They are, however, full of rather coarse sand and are probably unfit for any use.

Near the northeast end of Sugar Loaf Mountain a series of gray, green, and reddish shales is exposed. These rocks strike N. 40° E. to N. 50° E., and their dip varies from vertical to 70° NW. At some points they have decayed in place and are quite soft clays. The best deposits, however, lie just beyond the reservation limits and have been opened at several points there as well as in pits near the waterworks. At these places the clays have been excavated on a small scale for various purposes.

Analyses of specimens collected from these pits follow:

Analyses of clays from near the reservation line and from near the waterworks.

	A	B		A	B
Silica	73.96	70.29	Magnesia	.49	1.50
Alumina	14.54	16.74	Soda	.80	.08
Titanic oxide	.34	.64	Potash	2.64	2.76
Iron oxide	2.17	2.03	Combined water	3.76	5.00
Lime	.15	.10	Moisture	1.36	1.12

These analyses were made by George Steiger in the Survey laboratory. A is of clay from the pits near the reservation line and B is of clay from the pits of Mr. Arthur Furr, near the waterworks.

The most promising clay deposits of the district lie some distance north of those which have thus far been discussed. On Cedar Mountain, near Mountain Valley post-office, considerable work has been done in opening up large deposits of white clays. Two large cuts and a number of test pits give a good opportunity for the examination of this property

The principal or eastern opening shows 30 to 40 feet of light-gray clay with some interbedded light-yellowish clays and a few layers of light-colored sandstones. This series dips northwest at low angles (10° to 15°). On the south side of the mountain several pits show clay beds interbedded with heavy sandstones. The clays are 6 to 18 inches thick, and the sandstones about the same. These clays are mottled red and gray, but as they have been cut into for only a few feet the colors may change in further work.

The other large opening is about 3,000 feet west and shows 10 feet of light-gray clay overlain by 5 or 6 feet of thin sandstones with thinner interbedded layers of clay.

Analyses of these clays follow: A was collected from the principal east opening, B from the westernmost pit. Both of these were analyzed by George Steiger in the Survey laboratory.

Analyses of clays from Cedar Mountain.

	A.	B.		A.	B.
Silica	74.55	72.06	Magnesia	2.03	2.26
Alumina	13.68	15.31	Soda	.10	.15
Titantic oxide	.73	.95	Potash	3.84	4.53
Iron oxide	1.27	1.24	Combined water	3.63	3.50
Lime	.20	.17	Moisture	.77	.48

Uses of the clays.—So far as known the clays which occur within the limits of the reservation have never been utilized for any purpose. For this reason several opened deposits outside of the reservation were visited and sampled, and the information thus gained is presented in this part of the report.

When the analyses of all these clays are grouped together, as in the following table, it is seen that they are very closely alike in composition:

Analyses of clays, Garland County, Ark.

	1.	2.	3.	4.	5.	6.
Silica (SiO_2)	73.07	70.31	73.96	70.29	74.55	72.06
Alumina (Al_2O_3)	16.40	17.27	14.54	16.74	13.68	15.31
Titanic oxide (TiO_2)	1.09	1.00	.34	.64	.73	.95
Iron oxide (Fe_2O_3)	1.12	1.35	2.17	2.03	1.27	1.24
Lime (CaO)	.25	.23	.15	.10	.20	.17
Magnesia (MgO)	.64	.91	.49	1.50	2.03	2.26
Soda (Na_2O)	.26	.26	.80	.08	.10	.15
Potash (K_2O)	2.75	3.51	2.64	2.76	3.84	4.53
Water+ (100° C.)	4.46	4.36	3.76	5.00	3.63	3.50
Water– (100° C.)	.36	.88	1.36	1.12	.77	.48

1. Hot Springs Mountain, on reservation.
2. North Mountain, on reservation.
3. Sugar Loaf Mountain, on edge of reservation.
4. Arthur Furr's pits, near waterworks.
5. East pit, Worthington property, Mountain Valley.
6. West pit, Worthington property, Monntain Valley.

Specimens collected by E. C. Eckel, and analyzed in the laboratory of the United States Geological Survey by George Steiger.

A fact which is not brought out by analysis is that they differ greatly in the amount of sand contained, and this would have to be taken into account if any attempt should be made to use them. For present purposes, however, the analyses are sufficiently serviceable. Such clays can be used satisfactorily for the following products: (a) pressed brick or flooring tile, (b) second-grade fire brick, (c) body for art pottery.

They will probably all burn to a light-buff or cream color, and will give a dense body at medium burning temperature. At present the Mountain Valley clays are shipped in small quantity to Chicago for use in art pottery. The other clays have been used locally for brick, etc.

So far as the present investigation goes, it may be said that the clays on the reservation are of fair quality for the purposes above named, but that equally good clays occur outside of the reservation. The deposits on North and Hot Springs mountains, moreover, are so located that working them would greatly injure the appearance of the park. If it should be decided to work any of the reservation clays, it would be advisable to explore thoroughly the north flank of Sugar Loaf Mountain with the hope of finding clays there on the Government property; for at that point a clay pit would not injure the appearance of the park system. The clays though useful, are not of such great value as to justify damage to a public park.

CLAY RESOURCES OF NORTHEASTERN KENTUCKY.

By William Clifton Phalen.

A general description of the area here considered, as well as a sketch map (fig. 10, p. 260) showing its location, has been given in the paper on Coal Resources of the Kenova quadrangle (pp. 259–268).

All the clays of northeastern Kentucky are transported—that is, they have reached their present position through the agency of water. They may be divided, both as regards age and adaptability, into two classes: (1) The Coal Measures clays, and (2) the recent unconsolidated clays of the river and stream valleys. The former will be considered first. On pages 259–261 of this bulletin a brief description is given of the geology of this region. It is there stated that the lowest subdivision of the coal-bearing rocks in the western part of the field rests on the Greenbrier (Lower Carboniferous) limestone, and has been called the Pottsville formation.

COAL MEASURES CLAYS.

POTTSVILLE FORMATION.

Sciotoville clay.—A few feet above this Lower Carboniferous limestone is found one of the most important fire clays of northeastern Kentucky. This is the celebrated Sciotoville fire clay of the Ohio reports, less widely known as the Logan clay. It has been extensively mined at Sciotoville and in the region around Portsmouth, Ohio. In the Kenova quadrangle of the United States Geological Survey in northeastern Kentucky the horizon of this fire clay is below drainage except at a very few points. On Everman Creek, Carter County, about 1 mile above the residence of Mr. David Childers, 4 to 6 feet of the nonplastic clay show and have been mined. A short distance below Mr. Childers's house the limestone outcrops in the road apparently directly below the massive Sharon sandstone. The fire clay was not observed here. On North Fork of Oldtown Creek the fire clay was reported to George H. Ashley, of the Geological Survey, as being 5 feet thick and resting directly against the limestone and as usually being present without the limestone in the hills east of Tygarts Creek. West of Tygarts Creek the limestone is reported generally present, while little seems to be known of the fire clay.[a] This horizon may be looked for along the western outcrop of the Coal Measures, occurring as it does at the base of this system of rocks. When present it will usually be found a few feet above the Lower Carboniferous limestone and, in the absence of this terrane, occupying a similar position above the Waverly sandstone. Though its outcrop in the Kenova quadrangle is extremely limited, a few miles to the west its horizon is above drainage in nearly the entire valley of Tygarts Creek. At Olive Hill, in Carter County, it is now extensively worked by the Portsmouth Harbison-Walker Company and the Olive Hill Fire Brick Company, and it shows the following section at one of the openings of the former firm:

Section of fire clay at Olive Hill, Carter County, Ky.

	Ft.	in.
Coal		2–5
No. 3 clay	1–9	
Drab flint clay	1–9	
"Semihard" clay	1–5	
"Pink eye"	3	
Blue shale		18–20
Iron ore		4– 8
Top of Lower Carboniferous limestone.		

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[a] These statements refer to the territory included within the limits of the Kenova quadrangle.

This order of superposition is usually maintained in this district. It will thus be seen that there may be four distinct varieties of clay present in this noted seam. Of these the nonplastic drab flint clay is by far the most important and becomes the basis of refractory materials of the highest grade. The layer known as "semihard" is on a par with the clay at the horizon of the "Ferriferous limestone"[a] to be subsequently described, though by some of the clay workers the "Ferriferous limestone" clay, at least at some points, is considered superior. The "semihard" is a plastic or No. 2 clay and is mixed with the flint clay in various proportions, dependent on the desired quality of the product. No. 3 clay is also plastic, but of inferior quality to No. 2, while that called "pink eye" may be worked up into bricks, but the product is off color. The following analyses indicate the very high grade of the flint clay at this horizon, the percentages of silica and alumina approaching the theoretical values in kaolinite.

Analyses of flint clay.

	1.	2.	3.
Silica	50.95	48.56	46.75
Alumina	39.49	37.471	38.17
Iron oxide	....	Trace.	Trace.
Calcium oxide	....	.112	.17
Magnesium oxide	.28	Trace.	Trace.
Phosphoric acid	....	.255	....
Potash	.30	.289	Trace.
Soda		.283	
Water	9.18	[b] 13.030	14.03
	100.20	100.000	99.12

[b] Expelled at red heat.

1. Sciotoville fire clay; N. W. Lord, analyst: Ohio Geol. Survey, vol. 7, p. 58.
2. From ridge between Grassy and Three Prong creeks, Carter County, Ky.; sample collected by P. N. Moore; Robert Peter, analyst: Kentucky Geol. Survey, Report on Eastern Coal Field, vol. C, p. 10.
3. Near Olive Hill, Carter County; analysis furnished by Ashland Fire Brick Company.

Some of the clay from this horizon shows a rather high percentage of alumina, certainly higher than the kaolinite symbol calls for. Such clays are used for kiln brick and have the following composition:[c]

Analyses of high-alumina clays used for kiln brick.

	1.	2.	3.	4.	5.	6.
Silica (SiO_2)	43.38	44.52	43.05	40.30	40.80	42.71
Alumina (Al_2O_3)	40.35	40.81	44.60	45.00	49.00	38.88
Iron oxide (Fe_2O_3)	.85	1.03	2.60	n. d.	n. d.	3.36
Lime (CaO)	.88	.62	.40	n. d.	n. d.	.13
Magnesia (MgO)	.23	.55	.20	n. d.	n. d.	....
Carbon dioxide (CO_2)	13.41	12.11	9.00	n. d.	n. d.	15.19
Water						
	99.10	99.64	99.85	85.30	99.80	100.27

1, 2. Olive Hill, Carter County, Ky.; analyses from Stowe-Fuller Company's catalogue, p. 25½.
3-5. Hayward, Carter County, Ky. Ironton Firebrick Company.
6. Carter County, Ky. Chas. Taylor's Sons. F. W. Clarke, analyst. Specimen selected by E. C. Eckel.

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[a] The term "Ferriferous limestone" in this report will be employed in the sense that E. B. Andrews uses it in the reports of the Ohio Geological Survey.

[c] Analyses taken from Eckel, E. C., Cements, Limes, and Plasters, 1905, p. 491.

Other clays in the Pottsville formation.—There are other clay horizons below the Homewood sandstone which, however, have not come into prominence. In the eastern part of the city of Ashland the O'Kelly Fire Brick Company has opened up during the past summer the coal (No. 4) directly below the Homewood sandstone. This seam has the following section:

Section of coal No. 4 in the eastern part of Ashland, Ky.

	Ft.	in.
Roof, massive sandstone.		
Coal		18–19
Fire clay		10
Coal		8– 9
Fire clay	2½–4	

The company is now utilizing the clay associated with the coal at its plant in town with satisfactory results. The same seam with a very similar section[a] also occurs on Catletts Creek. Should the experience of the O'Kelly Company prove satisfactory, there is no reason why the bed on Catletts Creek should not be developed. At other points throughout the area this has proved a prominent clay horizon worthy of careful prospecting by those interested in the development of the clay resources of this area.

In the hills about the head of Johns and Fields branches, Carter County, between 2 and 3 miles northwest of Willard, a few prospect holes have been made on a bed of clay lying a few feet below the Homewood sandstone, and thus similar in position to that just mentioned as occurring in the eastern part of Ashland and on Catletts Creek. The openings have not been driven in far enough to give an accurate idea of the quality, and the clay seen on the outcrop is rather sandy, as would naturally result from the wash from the massive sandstone overlying it. The appearance and thickness of this bed warrant further prospecting. Other clay beds occur in this formation, generally associated with coal. As a rule these are too small to have commercial value.

ALLEGHENY FORMATION.

Clay associated with the "Ferriferous limestone."—As in the formation below the Allegheny, so also in this formation one clay horizon stands preeminently above the rest, as regards quality, distribution, and thickness. This is the fire clay occurring near the horizon of the "Ferriferous limestone" and lying from 10 to 40 feet above the Homewood sandstone. The following sections, one measured by George H. Ashley 1 mile west of Ashland, the other by the writer at Willard, give an idea of the associated beds.

Section of fire clay 1 mile west of Ashland.

	Ft.	in.
Light-brown sandstone	20+	
Coal	2+	
Light-drab clay	2	
Light-brown clay	6	
Dark-drab clay	1	6
Drab clay, with scattered iron-ore concretions ("Ferriferous limestone" horizon)	2	
Light-drab sandy shale	1– 2	
Drab shale		0–8
Dark-drab to black clay, grading into light drab at middle	1	6
Drab clay	3	
Flint clay		1–4
Drab clay	3	6
Dark-drab clay, almost black		3
Drab clay	8	

Four feet from the bottom of the lowest layer is about 1 foot of light-drab flint clay, similar to the best of the Pennsylvania flint clays.

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[a] See p. 263 of this bulletin.

Section of fire clay at Willard, Carter County, Ky.

	Ft.	in.
Fire clay		4
Coal		4
Bluish flint clay, reported		4
Dark plastic clay	4	
Light plastic clay, harder than the above	2	
Red iron ore (2 to 4 feet) Limestone (4 to 6 feet) } "Ferriferous limestone"	10	
Thin band of flint clay, formerly shipped to Olive Hill, Ky., and to Strasburg, Ohio.		

The flint clay shown in these sections is very persistent throughout the quadrangle, on account of its indestructible nature, and will serve as a valuable guide in locating the plastic fire-clay layer. The Willard section differs from that at Ashland in having the workable clay above the limestone, and not both above and below, as is the case in the section measured by Ashley, and also in a section measured by the writer at the fire-clay bank of William T. Johnson, west of Ashland:

Section at the William T. Johnson fire-clay mine, west of Ashland.

	Ft.	in.
Dark clay	4	
Limestone ore (sometimes replaced by 4 feet of limestone), averaging		6
Bone, not always present		2
Light-drab clay	2	

At the opening of the Petersburg Fire-Brick and Tile Company at Coalgrove, Ohio, the fire clay also occurs both above and below the limestone. A section measured by P. N. Moore at Amanda Furnace, about 4 miles northwest of Ashland, is quite similar to that obtained at Willard:

Section of fire clay near Amanda furnace.[a]

	Ft.	in.
Soil	4	
Clay shale	6	
Coal		4
No. 2 fire clay	3	
Pottery clay	4	
No. 1 fire clay	3	
Limestone ore		8
Top of "Ferriferous limestone."		

To the south of Ashland the dips up the Big Sandy carry this horizon below drainage level, but the rise of the beds south of Buchanan brings it again into the hills near Louisa and south of Fort Gay (Cassville), on the West Virginia side, where it has been prospected for on numerous farms on Mill Creek. To the southwest of Louisa it is generally present in the hills. On the farm of Mr. F. R. Bussey, at Busseyville, a good indication was seen 30 feet above the top of the Homewood sandstone, where Mr. Bussey reports 7 to 8 feet of clay. The rapid rise southward carries its horizon above the hilltops at the southern edge of the area. Between Busseyville and Prosperity it is present in most of the hills, and in this region the limestone is generally associated with the clay. To the northwest, on Cherokee and Irish creeks and Dry Fork, it is present, gradually descending to drainage level at Webbville. The basin between Webbville and Willard causes its disappearance between these points, but at Willard it is mined and shipped. The main continuous western boundary of this horizon is found in the hills just east of Little Sandy River, but at the head of Canes, Lost, and Oldtown creeks, in Greenup County, this horizon catches in the hilltops and the iron ore associated with the clay has been mined on the outcrop. In general throughout the area the old benches at this horizon will be a valuable guide in locating this clay, since the red limestone ore at this horizon was one of the most important sources of supply of iron ore in the days of the old charcoal furnaces, and was extensively benched.

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[a] Kentucky Geol. Survey, Report on the Eastern Coal Field, vol. C, p. 141.

Character of the clay.—The clay at this horizon, with the exception of the small band of flint, is of the plastic variety. As worked at Willard and at Ashland, it occurs in two benches—an upper dark bench 4 feet thick, and a lower lighter bench 2 to 3½ feet thick, generally of better quality. Moore's section at Amanda furnace shows an intermediate layer of potter's clay. At the Weaver Pottery Company's works, north of Catlettsburg, from 6 feet of clay the upper 3½ feet are worked, the lower portion being thought too sandy to work satisfactorily. The presence of pebbles of limestone has also caused the company some annoyance. The following analyses indicate the character of this clay. For comparison an analysis of the No. 1 or flint clay is appended.

Analyses of clay associated with the ferriferous limestone.

	1.	2.	3.	4.	5.
Silica	50.95	40.14	56.40	60.16	50.35
Alumina	39.49	43.72	28.00	25.55	33.07
Iron oxide	....	1.98		1.89	1.43
Lime	....	1.60	1.30	.00	.30
Magnesia	.28			.00	.15
Potash	.30	....	....	[a].08	....
Soda					
Water	9.18	12.56	14.30	12.37	14.30
	100.20	100.00	100.00	100.05	99.60

[a] By difference.

1. Sciotoville fire clay; N. W. Lord, analyst: Ohio Geological Survey, vol. 7, p. 58.
2. Upper stratum of clay at "Ferriferous limestone" horizon, Ashland, Ky.; Dr. Robert Peter, analyst. Furnished by the Ashland Fire Brick Company.
3. Lower stratum of same. Furnished by the Ashland Fire Brick Company.
4. Clay near Cassville, W. Va.; Laboratory of the mining department, Ohio State University; W. W Bornesberger and R. W. Mercer, analysts. Furnished by Charles Barnell, Cassville, W. Va.
5. Clay near Cassville; analysis by Norfolk and Western Railway. Furnished by Charles Barnell, Cassville W. Va.

Applications.—The clay at this horizon is a plastic or No. 2 clay and is used principally in the manufacture of fire brick, and to a less extent for blast-furnace crucibles, boshes, inwalls, coke-oven brick, etc. For the first purpose it is utilized by the Ashland Fire Brick Company and the O'Kelly Brick Company at Ashland and by the Petersburg Fire Brick and Tile Company at Coalgrove. The product mined at Willard by the Willard Fire Clay Company and the Fraley & Rice Company is shipped, that of the former goes to Olive Hill, where it is mixed with the flint clay to make No. 1 fire brick. The companies about Ashland import flint clay to mix with their product. To make a first-class refractory brick, from 67 to 80 per cent of flint clay is used, dependent on the uses to which the brick is to be put, the remainder being No. 2 or plastic clay. For a second-grade product these proportions are reversed. This clay is also locally suitable for pottery, and is being used for this purpose by the Weaver Pottery Company north of Catlettsburg. The product obtained near Amanda Furnace has been shipped to Cincinnati for the same purpose.

Other Allegheny clays.—In a cut on the Chesapeake and Ohio Railway, about a mile north of Louisa, 8 feet of sandy fire clay, or ganister, occurs at the level of the railroad track. This bed lies 18 feet below a layer of fire clay 1 foot thick, associated with which are limestone nodules, possibly the "Ferriferous limestone." At any rate the ganister occurs but a few inches below a fossiliferous horizon known to be lower Allegheny in age. This ganister bed was also noted in a cut on the Norfolk and Western Railway north of Fort Gay in a similar stratigraphic position. It does not seem to have attracted any attention, but its appearance is such as to indicate that it may have value.

Near North Kenova, Ohio, a clay was worked thirty years ago and hauled to Burlington and South Point, where it was utilized for pottery. The old workings are entirely fallen shut. The clay is found 25 feet above No. 8 coal and directly below a massive sandstone, thus occupying a position near No. 9 coal. This correlation is strengthened by its interval of about 85 feet above the Sheridan coal. This is the only known occurrence in the area of a workable clay at this horizon.

Other clay horizons locally workable undoubtedly exist, and many shale beds throughout the Coal Measures also appear promising and will probably be used in the future for paving bricks, sewer pipes, and for other purposes where inferior clays and shales may be utilized.

RECENT CLAYS.

The recent clays are found in the flood plains of the rivers and streams of the area and are very widespread, even the smallest streams having in some cases extensive deposits. The deposits worked at the present time are confined solely to the valley of Ohio River in the vicinity of Ashland, where there is local market and cheap coal and where transportation facilities are at hand. The flood-plain clay at the present time is used chiefly for ordinary red building brick, though it is adapted to the making of tile, shingle, etc. It is made into brick at the Means Russell plant west of the town, and by the J. J. Gates Company and the O'Kelly Brick Company in the eastern part of the city. Most of the brick is used in town, though some is shipped into other parts of eastern Kentucky and the adjoining State of West Virginia. The smaller flood plains contain clays which perhaps will not compare in quality with those of the larger river valleys, but which may be worked up into material suitable for local country use. Mr. F. R. Bussey has utilized such material from the flood plain of Harriet Branch of Little Blaine Creek. The deposit here is only 4 feet thick, but it illustrates the possibilities existing on all the smaller creeks. The flood plain deposits along Big Sandy and Little Sandy rivers have not even been prospected. Undoubtedly valuable deposits of clay exist along both these streams, which may be utilized later for common and pressed brick, roofing and drain tile, paving brick, sewer pipe, etc. Experiments having in view the adaptability of these flood-plain clays for the various purposes enumerated above should certainly be carried out.

CLAYS OF WESTERN KENTUCKY AND TENNESSEE.

By A. F. Crider.

INTRODUCTION.

During September and October, 1905, the writer was engaged in studying the stratigraphy of the embayment area in western Kentucky and Tennessee and in correlating the formations found there with those recently mapped in Mississippi. The most important products of the area are the extensive deposits of clays. The quality of some of these clays ranks in importance with the ball clays of Maryland, New York, and Ohio.

Common brick and stoneware have long been made in various parts of the district, but until recently little attention has been paid to the rich deposits of fire brick and ball clays. In fact there are now but two fire-brick plants in the entire district, and all the ball clays now being mined are shipped to potteries in Ohio, New York, and other States to be converted into the finished product.

LOCATION.

The area discussed embraces all that part of Kentucky and Tennessee lying west of Tennessee River and includes about 13,237 square miles (see map, Pl. XIII). It is a part of the Gulf embayment and is separated from the older and harder rock district on the east by Tennessee River. Ohio River forms the northern boundary from Paducah, Ky., to Cairo, Ill; Mississippi River forms the western boundary from Cairo to Memphis, Tenn., and the Tennessee-Mississippi line forms the southern boundary.

TOPOGRAPHY.

The region is a dissected plain with a maximum elevation along the southern border of about 600 feet above sea level. There is a low swell extending from north to south, parallel to and about 15 to 25 miles west of Tennessee River. The streams west of this divide flow west and empty into Mississippi River; those on the east side flow eastward and northward into Tennessee River. Throughout a large portion of the distance the divide is along the contact between the Cretaceous and the Tertiary, and it will be of interest to note that the great number of valuable clay deposits occur along the western slope of the divide near the crest.

GEOLOGY.

The oldest formations of this area belong to the Paleozoic rocks, which outcrop in all the treams east of Tennessee River and in a few places west of it. They become more deeply buried to the west beneath the Cretaceous and later deposits, and at the western edge of the area wells bored 1,200 feet deep fail to strike the Paleozoic rocks.

The deposition of the Cretaceous in this region therefore followed a period of deep erosion in which a great trough was scoured out at least 1,200 feet deeper than the basin now occupied by Mississippi River. This pre-Cretaceous trough extended in width from the Paleozoic hills in eastern Arkansas and Missouri to the present location of Tennessee River in Tennessee and Kentucky.

Cretaceous.—The Cretaceous is the oldest of the Gulf embayment deposits. It is a series of interstratified sandstones and clays in the lower part and limestones, marls, sandstones, and clays in the upper part. It occupies a narrow area on the east adjacent to Tennessee River. The area is widest to the south, where its width is about 31 miles. North of this it gradually narrows, and at Paducah, Ky., it is not more than 8 miles wide.

Tertiary.—Above the Cretaceous are the stratified sands, clays, and limestones of the Tertiary, with a total thickness of 2,000 feet or more. The lowest member of the Tertiary is an impure limestone and marl of Midway age, which outcrops in the southeastern section of the Tertiary area near the Mississippi line. North of this the marine deposits disappear or are covered so deeply by later deposits that they do not come to the surface. Immediately above the limestone noted above is the Porters Creek, a very persistent body of dark, slaty, nonfossiliferous clay which occupies a belt 2 to 6 miles wide and extends across Tennessee and Kentucky in a direction roughly parallel to Tennessee River. It forms the most easily recognized and important geologic horizon in the entire area. Except in the extreme south it forms the division between the Cretaceous and the remaining Tertiary and makes it possible to determine the age of the rich clay deposits of the district.

The Tertiary strata above the Porters Creek beds consist of interstratified sands, clays, and lignites. The sands predominate in the lower portion. The fine deposits of white, stoneware, and ball clays occur in these stratified Tertiary sands immediately overlying the Porters Creek clay.

Quaternary.—Over the entire Tertiary and Cretaceous areas is a thin veneer of Lafayette and loess which rests unconformably on the older strata. On account of these overlapping formations it is often difficult to obtain good exposures of the Tertiary and Cretaceous and the exact division line between them is in places impossible to determine. These surficial deposits are thickest on the bluffs adjacent to Mississippi River, where they reach a maximum thickness of 100 feet. They gradually thin to the east and at Tennessee River the maximum thickness is less than 25 feet and they are often wanting.

The large rivers and many of the streams in the interior have extensive bottoms which are covered with recent deposits.

DISTRIBUTION OF CLAY DEPOSITS.

CRETACEOUS CLAYS.

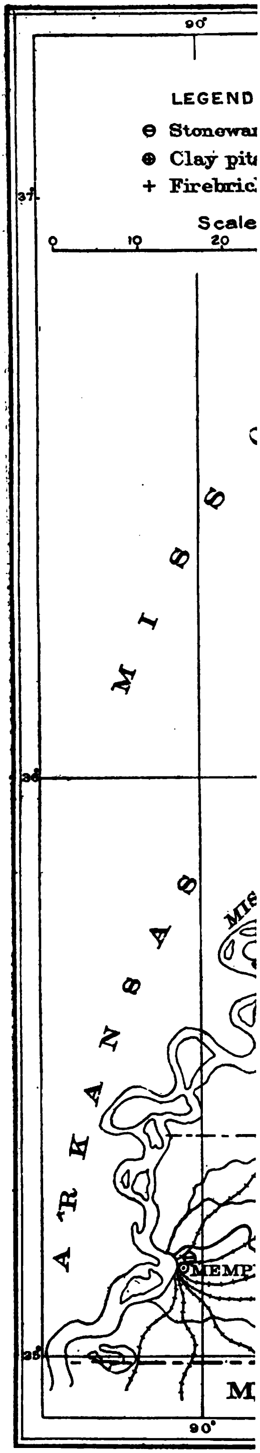
Clays belonging to the Cretaceous in this area are easily fusible and are usually of a dark or bluish color. They occur interbedded with sharp, fine-grained, micaceous sands.

Few of the Cretaceous clays have been developed. This is partially due to the fact that the deposits are generally too far removed from transportation facilities to be of value.

KENTUCKY.

Pottertown, Calloway County.—The Pottertown stoneware plant is located 6½ miles east of Murray, at Pottertown. Common jugware, churns, and crocks are the principal products. Only one turner is now employed, who turns about 50,000 gallons yearly. A small updraft kiln is used for burning ware. The ware burns to a beautiful cream color on glazing with Albany slip. The green ware can be put in hot sunshine after two days of drying in the shade.

The clay comes from a pit 200 yards east of the former post-office. It occurs in irregular lenses in the Cretaceous and is overlain by 3 to 6 feet of Lafayette. The clay varies in color from a cream white to a gray, purple, and black. It is underlain by a fine-grained, micaceous, variegated sand and is not used as it comes from the pit, but is mixed with the underlying sand in the proportion of five parts of clay to one part of sand. The principal market for the ware is at Murray and the small stores and farms throughout the country.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The following analysis of the Pottertown clay was made by A. M. Peter:[a]

Analysis of Pottertown clay, Kentucky.

Silica	57.840
Alumina	30.340
Iron peroxide	1.180
Lime	.011
Magnesia	.050
Potash	.618
Soda	.519
Water, etc	9.442
	100.000

TENNESSEE.

Hollow Rock, Carroll County.—About 2 miles west of the town, near the railroad, is a small pit of white, lean, siliceous clay. It is found in horizontal layers and if taken out when dry it breaks along the bedding plane. An area 25 by 40 feet has been opened up.

One mile farther west is another pit, in which occurs a bluish-pink, highly plastic clay free from grit. It is shipped to Nashville. The clay is exposed in a gully 30 feet long and 50 feet wide, and is overlain by 3 feet of Lafayette and, above this, by 2 feet of Columbia loam.

TERTIARY CLAYS ABOVE THE PORTERS CREEK.

The valuable clays which occur in great amount and variety in the Gulf embayment area of western Kentucky and Tennessee are principally found in the lower Tertiary. In Tennessee the area is restricted to a narrow belt of country 10 to 20 miles wide lying just west of the Porters Creek clay belt and can be traced across the State by a line of stoneware and fire-brick plants and pits which ship clays elsewhere to be made into the finished product.

In Kentucky the clays extend over a much wider belt, but they are confined within the limits of the lower Tertiary

KENTUCKY.

The Tertiary clays of Kentucky are still practically undeveloped. Most of the clays now being mined are shipped out of the State.

Dr. R. H. Loughridge,[b] who made a comprehensive study of the Jackson Purchase region of Kentucky, gave in his report the analyses of 41 different clays. Tests of the most important were made in the Rookwood Pottery, of Cincinnati, Ohio, and the results are given in the right-hand columns of the table of analyses (p. 420).

Wickliffe, Ballard County.—One of the most extensive clay deposits of Ballard County outcrops in the ravines and along the new railroad east of Wickliffe. Similar clay is exposed in the river bluffs between Wickliffe and Laketon. Near the surface it is gray, but it becomes whiter below. It makes a good fire brick and fancy decorated brick.

The thickness of the deposit is ascertained in the railroad section 1 mile east of Wickliffe. The section is as follows:

Section of clay deposit 1 mile east of Wickliffe, Ky.

	Feet.
Loess	30
Lafayette sand and gravel	20
Black, rotten clay, containing fragments of lignitized wood, bark, and logs	½
White plastic clay	30
Fine quicksand	3
Sand rock, bottom of cut.	

Samples of clay from this horizon have been made into fire brick and tested in the iron furnaces at Birmingham, Ala., where they are said to have stood a higher degree of heat than any other brick used at the furnaces.

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[a] Jackson Purchase region: Kentucky Geol. Survey, p. 107.
[b] Jackson Purchase region: Kentucky Geol. Survey.

Analyses of Tertiary clays from Kentucky[a] and Tennessee.

No.	Description and locality.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Potash.	Soda.	Water.	Color when burned.	Shrinkage (per cent).
1	White clay, 1 mile east of Wyatt's schoolhouse, Calloway County, Ky.	46.020	38.980	Trace.	0.773	0.136	0.309	0.172	13.610	Brown, white when glazed.	
2	Howard's pottery, Rock, Graves County, Ky.	56.980	32.160	2.160	Trace.	.209	.838	.111	7.542	Cream	
3	do	62.680	25.880	2.900	Trace.	.319	1.147	.928	6.146	White, unglazed	10
4	Panther Creek, 6 miles east of Mayfield, Graves County, Ky.	75.550	16.751	1.198	Trace.	.144	1.094	.216	5.047	Salmon	
5	Fire clay, Wickliffe, Ballard County, Ky.	73.240	15.760	1.920	.325	.519	1.467	.147	6.622	Buff	
6	Bluish-white clay, southwest of Blandville, Ballard County, Ky.	74.460	18.070	1.633	.314	.245	.940	.210	4.317	Buff	15
7	White plastic clay, Cane Creek, 2 miles north of Wickliffe, Ballard County, Ky.	63.840	26.040	.740	Trace.	.137	.714	.207	8.322		
8	Purplish-gray clay, Laketon, Ballard County, Ky.	67.501	23.051	2.109	.257	.065	.412	.020	6.585		
9	Four miles south of Blandville, Ballard County, Ky.	71.940	20.700	Trace.	.370	.350	.630	.000	6.200	White	
10	Plastic clay, 4 miles northeast of Milburn, Ballard County, Ky.	76.540	14.820	.960	Trace.	.331	.926	.229	6.194	Light gray	
11	Bluish plastic clay, 3 miles east of Blandville, Ballard County, Ky.	71.180	20.800	1.780	Trace.	.101	.247	.291	5.601		
12	Purplish plastic clay, 3 miles east of Lovelaceville, McCracken County, Ky.	66.320	22.930	1.190	.437	.209	1.107	.470	7.377		
13	Stiff plastic clay, 3 miles south of Wingo, Graves County, Ky.	75.120	15.960	1.420	Trace.	.317	1.351	.245	5.587	Brown	7½
14	Plastic clay, north of Boaz, Graves County, Ky.	61.920	30.060	.300	Trace.	.064	1.602	.239	5.815	Milk white, unglazed.	
15	Plastic clay, bluff above Columbus, Hickman County, Ky.	85.180	10.260	1.120	Trace.	.064	.954	.146	2.276		
16	do	84.918	10.560	1.102	.572	.108	.651	.000	2.089	Light cream color	
17	Clay from "chalk banks," 2 miles below Columbus, Hickman County, Ky.	76.360	14.951	2.109	.325	.173	1.171	.125	4.786		
18	Greenish sandy clay, 1 mile north of Hickman, Fulton County, Ky.	71.340	17.190	2.770	1.612	.209	.925	.232	5.722	Light gray buff	
19	Greenish sandy clay in Hickman, Fulton County, Ky.	83.380	9.800	2.120	.963	.187	.617	.118	2.815	Light brick color	
20	Greenish indurated joint clay, lower part of bluff at Hickman, Fulton County, Ky.	77.960	13.970	2.390	.134	.163	.797	.124	4.462	Brownish buff	
21	Indurated clay, 45 feet above low water, Hickman, Fulton County, Ky.	64.800	21.070	5.270	1.400	.050	.646	.202	6.562	Light buff	
22	Slate-colored, refractory joint clay, Hickman, Fulton County, Ky.	74.100	16.460	2.700	.358	.187	.559	.135	5.501	Light brown	
23	Green, refractory clay, underneath clay No. 22, at Hickman	83.500	9.940	2.500	.358	.173	.539	.109	2.881	Light brick color	

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[a] Rept. Kentucky Geol. Survey, pp. 100-118.

A small amount of the clay is shipped to the Union City Tile Company at Union City, Tenn., where it is mixed with common surface clay for making drain tile.

Nos. 15 and 16; Columbus, Hickman County.—These clays came from the bluff above Columbus, 65 feet above low water. They are highly siliceous, containing 85.18 per cent of silica and 10.26 per cent of alumina. The plasticity is due to the fine division of the silica.

One mile up the river from Columbus, at the point where the river leaves the bluff, is a lens of chocolate-colored plastic clay containing numerous leaf impressions and fragments of lignite. The clay is embedded in the coarse sand which outcrops along the bluff from this point to Columbus. It is used at the Rucker stoneware plant at Columbus.

No. 19–23; Hickman, Fulton County.—The bluff at Hickman rises about 180 to 200 feet above the river and contains about 105 to 115 feet of greenish joint clay and clay stone. This is overlain by 10 to 20 feet of Lafayette sand and gravel, and this in turn by 65 to 70 feet of loess.

The clays vary from a highly siliceous clay stone to a plastic joint clay. Clays Nos. 19, 20, 22, and 23 are quite refractory before the blowpipe.

The clays were analyzed by Dr. A. M. Peter,[a] who says:

> It is quite evident that the Tertiary bluffs from which these clays were collected offer some valuable materials to the industrial arts. Some of these are quite refractory, especially Nos. 19, 20, 22, and 23 [of this report], and would probably make good fire bricks, etc. Others could be employed for terra-cotta work and other forms of pottery, while some of these abundant deposits might, no doubt, be used with advantage in mixture with the more calcareous soft material found in some of these beds in the manufacture of hydraulic cement of the character of the celebrated Portland cement.

None of the Hickman clays are being worked.

Pryorsburg, Graves County.—The largest output of clay from any of the Kentucky deposits comes from the Kentucky Construction and Improvement Company's pit, 1 mile north of Pryorsburg. The clay was first discovered in a small outcrop on the north side of a small hill near the main line of the Illinois Central Railroad. A bed 20 feet thick and with a strong dip to the south is now being worked by open pit and tunnel. Holes have been bored into the clay to a depth of 100 feet without penetrating the deposit.

The clays consist of fine white ball and sagger clays used for making chinaware, insulators, and decorated tile. A large per cent of the output is shipped to East Liverpool, Ohio. Mr. M. B. Cooley is general superintendent.

Rock, Graves County.—A small stoneware plant is located at Rock, in the southeast corner of Graves County. Only the common ware, such as jugs and churns, is made here.

The clay used at this plant comes from a pit near the former post-office. These beds occur in lenses about 100 feet long, 40 to 50 feet wide, and 2 to 15 feet thick. There are usually a large number of lenses near together. The clay is very low in silica and high in alumina, and burns to a white-cream color. The ware is burned in updraft kilns. The owners of the plant are W. B. Howard & Sons.

PORTERS CREEK CLAY.

In Kentucky and the larger part of Tennessee the Porters Creek clay, commonly called "soapstone," forms the lowest visible member of the Tertiary. It consists of a black, stiff joint clay, containing a large amount of fine sand and mica. It carries a high per cent of iron and burns to a pink color. In speaking of this clay Dr. R. H. Loughridge[b] says:

> Tests made at the Rookwood Pottery indicate that it can not be used for glazed ware because of the shivering of the glaze. It might be successfully used in the manufacture of water jars, which require no glazing. The unglazed biscuit is pink in color. When mixed with an equal weight of the white plastic clay from Russell's pottery (Pottertown) east of Murray, it receives a good glaze and makes a light chocolate-colored ware, dotted with black specks from the mica particles.

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[a] Jackson Purchase region: Kentucky Geol. Survey, p. 100.
[b] Op. cit.

TENNESSEE.

Peryear, Henry County.—A new fire-brick plant is now being built at Peryear by the Dixie Fireproof Brick Company, of which Mr. Thomas H. McElrath is superintendent. The clay is ground in a machine run by steam and mixed with crushed brick in the proportion of two-thirds clay and one-third grog. The plant is fitted up with an artificial drier, but in the summer and fall the bricks are dried on covered racks in the open air. It requires about eight to ten days for air drying and twenty-four hours to dry by steam. One round down-draft kiln has been completed and preparations are being made to add two or three other kilns.

The pit from which the clay is obtained is about 200 feet west of the railroad track on the south side of the town. The plant is built on the east side of the railroad track. The clay is reported to be 65 feet thick, and is divided into different beds. The following beds have been analyzed and tests have been made of each:

Clay beds at Peryear, Tenn.

	Feet.
First stratum from the top	3- 6
Second stratum from the top	4½- 5
Third stratum from the top	12-13
Fourth stratum from the top	4
Fifth stratum from the top	4
Sixth stratum from the top	3
Seventh stratum from the top	3½

Clay from stratum No. 1 is a fine ball clay. Besides being used for making fire brick it has been shipped to Chicago, Ill., Milwaukee, Wis., and Columbus, Ohio, for use in the manufacture of asbestos cloths, etc., and also to Iola, Kans., for making retorts. The clay is gray when fresh, but becomes white when dry.

Experiments have been made with the clay for making a hard enamel for decorated tile. The following formula has given the best results:

Formula for making enamel for decorated tile.

	Pounds.
Ball clay	17
Red lead	3
Whiting	10
Flint	20
Feldspar	50
Sal soda	1
Zinc oxide	15

When made according to the above formula, one pint of the mixture should weigh 32 ounces. It requires 2,200° to 2,300° F. to fuse the mass, and it will stand 2,900° F.

Whitlock, Henry County.—Three large clay pits located in Henry County are owned and operated by Mr. I. Mandle, of St. Louis, Mo. The "Mandle pit" is located about 3 miles west of Whitlock. It was opened in 1897 and has been worked constantly since that time. The clay is hauled to Whitlock in wagons, and shipped to East Liverpool, Zanesville, and Cincinnati, Ohio; Covington, Ky.; and Victor, N. Y. This pit furnishes the Tennessee ball clay No. 1 and No. 3, used for making chinaware and decorated tile.

The clay is worked by an open pit, which is now 250 feet long and 200 feet wide. Thirty-five feet of coarse red and yellow sand are now being removed from above the clay. Twelve teams and scrapers are used to excavate the sand, which is carried back into the pit from which the clay has been removed. The following is a section of the pit:

Section in Mandle clay pit, Henry County, Tenn.

	Feet.
9. Columbia loam	5
8. Red semistratified sand	5
7. Stratified white and yellow sand, very coarse, with an occasional lens of impure gray clay	30

	Feet.
6. Pink plastic clay	¼– 1
5. Black to chocolate-colored rotten clay containing small particles of iron pyrite, fragments of lignitized wood, and a few leaf impressions	½– 2
4. White ball clay which is considered the strongest clay in the pit	2
3. Black rotten clay similar to No. 5	1– 2
2. White ball clay, very plastic, and similar to No. 4	8–12
1. Gray clay similar to the above except that it contains a slightly larger amount of free silica	4

The clay is assorted in the pit into four classes. The finest ball clay is found in beds Nos. 4 and 2.

The Monroe pit, owned by Mr. I. Mandle, is located one-fourth mile west of the railroad and 3 miles north of Whitlock. A side track has been put in, and the clay is hauled from the pit in wagons and loaded into the cars. The section is as follows:

Section in Monroe clay pit, Henry County, Tenn.

	Feet.
Lafayette gravel and sand	8
Red stratified sand	10–12
Yellow semiplastic, stratified, sand clay with thin bands of rock one-fourth to one-half inch thick	5
Gray plastic clay	10
Black clay similar to the black rotten clay near the top of the clay deposit in the Mandle pit 3 miles west of Whitlock. This is mixed with the other and shipped as a sagger clay	12

The clay lies in horizontal strata. The principal use is for wads and saggers.

The Claxton clay pit, of which Mr. I. Mandle is owner, is located three-fourths of a mile east of India. It was opened in 1898. The clay, which has a strong dip to the south, was first discovered in the road. The formation of the clay is very similar to that at the Mandle pit 3 miles west of Whitlock. The area now opened is in two chambers. The east-west opening is about 100 by 100 feet, and the north-south opening 50 by 100 feet. The section on the south side of pit is as follows:

Section in Claxton clay pit, Henry County, Tenn.

	Feet.
Red Lafayette sand	15
Thin band of black rotten clay	1
White ball clay containing stains of iron oxide	6 – 7
Black rotten clay same as upper clay layer 1½ feet thick at north end of pit, but thickening to 2½ feet at the south end	1½– 2½
Gray, tough ball clay, white when dry, 4 feet thick at north end, and 5 feet thick at south end	4 – 5
Thin band of black rotten clay	⅓– ½

A well recently bored about 100 yards south of the pit struck the clay at a depth of 16 feet and passed through it at a depth of 32 feet. Coarse yellow sand was found below the clay and a fine stream of water was struck at a depth of 60 feet.

The three Mandle pits in Henry County furnish Tennessee ball clay No. 1 and No. 3, besides sagger, wad, and stoneware clays. These various kinds of clays occur in the same pit. The ball clays are found in the upper part of the deposit, which gradually grades into the wad and more common clays below.

The ball clays are used by white-ware and art potteries, encaustic tile manufactories, electric and porcelain works, and enameling, stamping, and terra cotta concerns.

Tennessee ball clay No. 1.—This is a highly plastic clay, which mixes well with water, and when washed through a 120-mesh sieve leaves but little residue. The clay fuses at Seger cone No. 8 and has a total shrinkage of 15 per cent, or about one-seventh. At this heat it burns to a white-creamish color.

The rational analysis of Tennessee ball clay No. 1 is as follows:

Analysis of Tennessee ball clay No. 1.

Clay substance	86.20
Feldspar	2.70
Flint	11.10

Tennessee ball clay No. 3.—This clay has a brown color when dry, mixes well with water, and will pass through a 120-mesh sieve without residue. By passing it through a 175-mesh sieve it leaves 10 per cent residue, which consists mainly of fine sand.

The shrinkage at cone 1 is 12.5 per cent, or one-eighth; at cone 8 the shrinkage is 18 per cent, or about one-sixth. The color of the clay at cone 0.010 is white; at cone 1 the color is still white, and at cone 8 it fuses to a gray body.

The rational analysis of Tennessee ball clay No. 3 is as follows:

Analysis of Tennessee ball clay No. 3.

Clay substance	91.35
Feldspar	2.70
Flint	5.95

The location of the Peryear pit and of the three Mandle pits described above throws much light on the age of the fine deposits of ball and sagger clays in this section of the State.

The lowest member of the Tertiary which has been recognized in Henry County is the Porters Creek clay or "soapstone." It occurs in the deep ravine at Conyersville, 3 miles east of Peryear. According to barometric measurement, the Porters Creek clay at Conyersville is 50 feet lower than the clay pit at Peryear. Wells 100 feet deep at Peryear get water before reaching the Porters Creek clay. The dip to the west is therefore at least 30 feet per mile. The Mandle pits, located 3 miles west and north of Whitlock, are at least 5 miles west of the Porters Creek outcrop, and are therefore in the lower Tertiary. The age of the ball clay near India is not so certain. The Porters Creek clay outcrops in the deep ravine just east of Paris and along the railroad for 3 or 4 miles to the southeast. A line drawn from Paris to Conyersville would pass near India. This line, however, represents the western edge of the Porters Creek clay, which is usually 3 to 4 miles wide. The elevation of the India pit is 400 feet above sea level, barometric reading, or about 20 feet lower than the most western outcrop of the Porters Creek clay at Paris.

Paris, Henry County.—A small stoneware plant is located 1½ miles east of Paris on the Louisville and Nashville Railroad. It is owned and operated by John T. Currier. The clay is ground and tempered in a 2-horse pug mill with a capacity of 11,000 pounds per day. The clay is used as it comes from the pit. Twelve hours after turning the ware can be placed in the sunshine without checking. Two kilns are in use, with a combined capacity of 5,000 gallons. The ware is glazed with Albany slip.

The clay comes from a pit one-half mile northeast of India, on the west side of the road. It underlies 4 to 5 feet of Lafayette sand and gravel. The clay has but little grit, is gray to light chocolate in color, and contains very small flakes of mica.

Hico, Carroll County.—White stoneware clays are dug from pits 3 miles southeast of McKenzie and shipped to potteries at East Liverpool and Akron, Ohio, and Louisville, Ky. Similar clays occur along the Louisville and Nashville Railroad just south of McKenzie.

Gilmore, Madison County.—The Southern Tile and Brick Works has the largest and most complete brick plant in the State. The plant is located at Gilmore station, 5 miles north of Jackson, on the Mobile and Ohio Railroad. Mr. X. B. Wickersham is general manager. It has been in operation since 1903. Fireproof, dry press, and stiff-mud bricks are manufactured.

The clay for the fire brick is ground in a Wallace pug mill and molded in a side-cut stiff-mud machine. Common clinker is used instead of grog. The clinker completely burns up and leaves the bricks porous and thus permits them to expand on heating. The output is 20,000 bricks per day.

The bricks are taken from the machine and placed upon a 30 by 46 inch pallet, which rests upon a stationary frame made over a small steel track. Each pallet will hold 120 bricks or more. When full, a patent brick car is pushed underneath the pallet, and by a patent lever the load is transferred to the car. The car is then pushed on the steel track to the drier and the pallets are deposited upon a long rack, where they remain until the bricks are dry. After they are dry enough to set in the kiln the bricks are conveyed on the car to the kiln. They are therefore handled but twice before burning.

In the summer and fall months the bricks are dried in the open air on covered racks, about eight days being required for drying. A hot-air drier is used in cold or damp weather. Bricks will dry in the hot-air drier in twenty-four hours.

A steam drier was first used, but the pipes soon began to leak steam, which condensed on the bricks and retarded drying. The hot-air drier has proved much more efficient. Five kilns are in operation—four rectangular kilns, which hold 185,000 each, and one round down-draft with the same capacity. All the kilns are made of fire brick and fire bricks can be burned in them. Wood and coke are used in the kilns until they become red, and coal is used for the heavy burning. It requires about 20 cords of wood, half a car of coke, and 20 tons of coal for burning a kiln of 185,000 bricks.

In addition to the common kind, the company makes various fancy-colored, dry-pressed bricks. The variety of colors is obtained by combining the fine white clays with the common yellow loam in various proportions. Chattanooga manganese is used for making spotted bricks.

The clay used for making fire bricks and fancy-face bricks comes from a pit about 100 yards west of the railroad. It is a gray, highly plastic clay, which belongs to the Wilcox formation of the Tertiary. A thorough investigation of the clay was made before the plant was erected, and it was found to be 30 feet thick and to cover an area of several acres.

The following is an analysis of the clay, furnished by Mr. X. B. Wickersham:

Analysis of clay from Gilmore, Madison County, Tenn.

Moisture	0.98
Silica	77.83
Alumina	16.16
Ferric oxide	2.86
Loess	2.17
	100.00

Combined water substances were unsought.

The white clay is overlain by about from 5 to 10 feet of Columbia loam, which is used for making the common dry-pressed and stiff-mud bricks. Fire bricks are shipped to various places in Tennessee, Kentucky, Mississippi, Alabama, Arkansas, and Louisiana. Fire clay is ground and shipped in small sacks for making the mortar in which the fire bricks are set. It requires thirteen men to operate the stiff-mud machine, and nine men for the dry press.

Pinson, Madison County.—A large plant has been erected near Pinson for the manufacture of fire brick, stoneware, tiles, and common mud brick. It is operated by Messrs. Robins & Henderson.

The fire bricks are made from a mixture of white plastic clay and sand in the proportion of three parts clay to one of sand. Sawdust is used instead of grog. The production is about 30,000 bricks per day.

The stoneware is made from the same clay as the fire brick. The ware is turned on wheels run by steam and is dried on an artificial heater. The Stewart patent down-draft kiln is used. Wood is used for fuel, about 15 cords per kiln being required. The production is 2,500 gallons per day. Albany and Seneca Falls slips are used for glazing ware. The Seneca Falls slip gives a bright-olive glaze. When combined with the Albany slip it gives a pale-greenish tint.

The clay used at the Robins & Henderson plant comes from pits located about 2½ miles southwest of Pinson. The clay occurs in small lenticular bodies with a maximum thickness of 20 feet. A large number of these bodies are found in a small area.

Mr. Henry Weiss operates some clay pits 3 miles southwest of Pinson. Clay is shipped to Memphis and Chattanooga stoneware plants.

The clay used in the Jackson, Tenn., pottery is obtained from pits 3½ miles southwest of Pinson. The pits are operated by Mr. C. M. Morrow.

The white clays in the Pinson district occur in the lower division of the Tertiary. The Porters Creek clay outcrops as far east as Henderson and is overlain by the coarse variegated sands in which the white plastic clays are found. These clays occupy much the same geologic position as the ball clays near Whitlock, Peryear, and India, in Henry County, the white clays near Hico, in Carroll County, and at Saulsbury and Grand Junction, in Hardeman County.

Grand Junction, Hardeman County.—A small stoneware plant, operated by Mr. W. T. Follis, is located in Grand Junction. Two turners are employed, who manufacture 350 gallons per day. The ware is burned in a down-draft 16-foot kiln. Five or six tons of coal are required for each kiln.

The clay used in the Follis plant comes from the Hancock pits, located along the Illinois Central Railroad track, three-fourths of a mile southwest of Grand Junction. It occurs below the Lafayette sands, the lower portion of which is cemented into a conglomerate. The clay is exposed to a thickness of 20 feet and is used as it comes from the pit.

The Irwin Clay and Sand Company has an extensive deposit of white clay and sand 1½ miles east of the city. Part of the clay is shipped to the Memphis pottery for making stoneware. Molding and glass sands are also shipped.

Stoneware clays have been shipped from the Pinson and Prewitt pits located one-half and one mile, respectively, west of the station. Neither of these pits is worked constantly. White clays are also mined and shipped from Saulsbury, 5½ miles east, and from Lagrange, 3 miles west of Grand Junction.

PRODUCTION.

There are in the Kentucky-Tennessee district under discussion fourteen plants engaged in the manufacture of stoneware and red earthenware. All of these plants derive their clay from pits in the district. The following is a list of the stoneware plants:

Stoneware plants in Kentucky and Tennessee.

- Kentucky:
  - J. A. Bauer, Paducah.
  - W. K. Russell & Son, Pottertown.
  - W. B. Howard & Son, Rock.
  - Geo. W. Myatt, Tompkinsville.
  - Wickliffe Pottery, Wickliffe.
- Tennessee:
  - W. T. Follis, Grand Junction.
  - Jackson Pottery Company, T. J. Connor, lessee, Jackson.
  - C. Sparks, McKenzie.
  - Memphis Stoneware Company, Memphis.
  - John C. Currier, Paris.
  - Pinson Pottery, Pinson.
  - Toone Pottery Company, Toone.

The value of the product for 1904 was distributed as follows:

Value of product in Kentucky and Tennessee stoneware plants, 1904.

Tennessee:	
Stoneware	$98,000.00
Red earthenware	250.00
	98,250.00
Kentucky:	
Stoneware	84,150.00
Red earthenware	10,400.00
	94,550.00

A large per cent of the clay mined is shipped to places outside of the district. The following is a list of the clay miners:

Clay miners, Tennessee and Kentucky.

Name.	Kind of clay shipped.
Prewitt & Hurst, Grand Junction, Tenn	Stoneware.
R. H. Breedlove, Henry, Tenn	
J. C. Cleaver, Hollow Rock, Tenn	Stoneware.
Mineral Springs clay mine, Paris; mine at India, Tenn. John N. Jackson, proprietor.	Stoneware.
L. J. Irwin, Grand Junction; mine at Irwinton, Tenn	Stoneware.
Andy Pate, McKenzie, Tenn	Fire clay.
Tennessee Ball Clay Co. of Clarksville; mine at McKenzie, Tenn	Fire clay.
F. M. Wright, Paris, R. F. D. No. 4; mine at Nobles, Tenn	
I. Mandle, 3943 West Pine st., St. Louis, Mo.; mines at Whitlock and India, Tenn.	Ball, fire, sagger, and wad clays.
J. L. Roark, Paris, Tenn	
Peryear Clay and Mining Co., Peryear, Tenn. R. W. Beale & Sons, proprietors.	Ball, fire, and stoneware clays.
Kentucky Construction and Improvement Co., Pryorsburg, Ky. C. P. Henderson, president.	Ball clay.

The total amount and value of clay shipped from the district in 1904 was as follows:

Shipments of clay from Tennessee-Kentucky district, 1904.

	Tons.	Value.
Fire clay	8,695	$8,908.00
Ball clay	21,350	69,225.00
Stoneware clay	11,600	11,175.00
Miscellaneous clays	1,800	2,250.00

BRICK INDUSTRY.

Common building brick forms the largest clay product in the district. There are 43 brick plants, which produced in 1904 62,541,000 common bricks, valued at $400,318; 280,000 fire bricks, valued at $4,600; 200,000 face bricks, valued at $2,000; and $12,700 worth of drain tile. It will be seen from the above figures that the average retail price for common bricks is $6.40 per thousand.

CLAYS OF THE PENOBSCOT BAY REGION, MAINE.

By Edson S. Bastin.

Area covered by field studies.—The field observations on which this paper is based were confined to the coastal region and extended from Bluehill Bay on the east to Pemaquid Point on the west, taking in nearly all of the islands which border this part of the mainland. That portion lying to the east of Thomaston was studied during the summers of 1904 and 1905, while making a detailed geological study for folio publication of the Penobscot Bay and Rockland quadrangles. The coast from Thomaston to Pemaquid Point was studied hastily during a reconnaissance trip in the autumn of 1905, made principally for the purpose of tracing the limits of certain granite areas.

Distribution.—The clays of this district are distributed over the lowlands of the coastal region as a nearly horizontal sheet of varying thickness. So uniform is the material in grain and color that only here and there can a division into distinct beds be recognized. Vertically they are confined mainly to the interval between sea level and the 125-foot level, and while not all the land within this interval is occupied by these deposits it is probably safe to say that they cover fully half of such territory. Areally they find their broadest distribution and penetrate farthest inland along the rivers and tidal estuaries, while along certain bold parts of the coast they may be entirely absent. Along Penobscot River they are well developed as far up as Bangor and along St. George River they penetrate inland a distance of 20 miles to the villages of Thomaston, Warren, and beyond.

General appearance of the clays.—The clays here considered, which are the only commercially important clays of the region, are yellowish gray to blue-gray in color, the former being by far the more common. For the most part they are exceedingly fine grained and except in a few localities are very free from sand or pebbles.

Recognition in the field.—The clays are readily recognized where they have been exposed by the waves or streams and where they have been uncovered in excavations. Excellent natural exposures occur at Sherman Cove, near Camden, along the north side of Rockland Harbor, along St. George River near Thomaston, and at many other localities on the shore, where they have been cut into by the waves and now stand up as benches or terraces rising 10 to 25 feet above the beach. Artificial exposures are common in the railroad cuts and in the cuts and ditches of many of the wagon roads. One of the best exposures is at the brickyard at Thomaston, and other good exposures occur at the quarries west of Rockland, where the clays must be stripped off before the limestone can be reached. Even where sections can not be found, the presence or absence of the clays may usually be recognized from the general appearance of the land surface. Extensive flats or gently sloping plains occupying the lowlands and free from surface bowlders are nearly always found to be built up of these clays. When roads traversing these flats have not been graded with materials brought in from other localities, the clayey character is revealed by the fine light-gray dust which develops in dry weather, the sticky gray mud which forms after a heavy rain, and the absence of pebbles or cobbles.

Depth.—The depth of the clay deposits varies greatly, being in general greatest on the lowlands and least on the higher hill slopes. Depths of 15 to 35 feet are very common, and well records in some cases seem to show a depth of from 50 to 75 feet. The record of a well at the brickworks in Thomaston showed 45 feet of clay resting upon limestone.

Age and origin.—The distribution of these clays with respect to the present coast line at once suggests their marine origin, and such a conclusion is sustained by the presence here and there within the clays of the shells of marine animals. The clays represent, in truth, old clam flats formed at a time when the sea level was considerably higher, relative to the land, than it is at present. Their age is fixed by their relation to the deposits made by the glaciers which covered the State in the Pleistocene period. In several localities they were seen to overlie deposits of glacial bowlder clay, while they were overlain in turn by gravels deposited by streams flowing from the melting ice; they were deposited therefore during the glacial occupation. The streams flowing from the melting glaciers were heavily laden with sediment; the coarser portions, the gravels and sands, were deposited on the land surface or in the ocean close to the shore, but the finer portions were carried farther out and deposited as these beds of marine clay. They differ from the clam flats of to-day only in the greater rapidity with which the muds were deposited.

Present utilization in brickmaking.—These clays, in common with the limestone and much of the granite of Maine, possess the commercial advantage of proximity to the coast, where the manufactured product can be easily and cheaply shipped by water. Plants for the manufacture of common brick are numerous along the lower portion of Penobscot River; near Damariscotta, on Damariscotta River; and at other localities within the area under discussion. Within the Rockland quadrangle there is only one company engaged in brick manufacture; this is the Thomaston Face and Ornamental Brick Company, with a plant in the eastern part of the village of Thomaston. This plant is given special mention because it has been studied by the writer in more detail than other plants, and because its modern equipment seems to point out the lines to be followed in the future development of these deposits. The clay at this brickyard is buff gray in color and free from pebbles or concretions. As it occurs in the banks it is moderately dry. It is dug by steam shovel and transferred in small cars to the disintegrator, where it is dry crushed. The clay is worked by the stiff-mud process, the dry material being carried by a belt from the disintegrator to a Raymond pug mill, where it is mixed with about 20 per cent of water and fed into a Raymond "999" brick machine provided with an automatic down-cut cutting table. This machine has a capacity of 8,000 to 12,500 standard side-cut bricks per hour. The bricks are dried in a 10-tunnel drier having a capacity of 75,000 bricks. The burning is done in an ordinary scove kiln. The bricks show an air shrinkage of one thirty-second of their length and a fire shrinkage of one sixty-fourth, and incipient fusion takes place at about 3,000 °F. The product goes principally to Massachusetts and is shipped by rail, although water shipment is equally feasible. At present the company's product does not correspond to its name, for its whole output is common brick; but the clay is considered to be of too high a grade for use solely for this purpose, and the company is now installing machinery for the production of pressed brick.

Chemical composition.—In the table below are given analyses of clays from three localities within the Rockland quadrangle:

Analyses of clays from Knox County, Me.

	1.	2.	3.
Silica (SiO_2)	62.80	62.33	61.59
Titanium oxide (TiO_2)	.87	.79	......
Alumina (Al_2O_3)	17.36	17.70	19.10
Ferric iron (Fe_2O_3)	4.40	5.19	7.53
Ferrous iron (FeO)	[a] 2.00	[a] 1.72	
Lime (CaO)	.88	1.00	1.68
Magnesia (MgO)	1.58	1.53	1.87
Soda (Na_2O)	1.48	2.38	......
Potash (K_2O)	3.05	2.41	......
Water (at 107° C.)	1.31	1.11	5.51
Water (on ignition)	4.39	3.81	
Carbon dioxide (CO_2)	None.	None.	
	100.12	99.97	97.28

[a] The values reported for ferrous iron are questionable on account of the presence of a small amount of organic matter.

1. Clay from brickyards at Thomaston, Me. W. F. Schaller, analyst, U. S. Geological Survey laboratory.
2. Clay from Hayden Point, near South Thomaston, Me. W. F. Schaller, analyst, U. S. Geological Survey laboratory.
3. Clay on the property of the Rockland-Rockport Lime Company, near Rockland, Me.

Although these three samples were taken at localities several miles distant from each other their analyses are closely similar, a fact which suggests that throughout this region the clays possess a rather uniform composition. From the chemical analyses and also from a microscopic examination it is seen that these are not what could be called "sandy" clays, though the amount of sand is sufficient so that none need be added in mixing for brickmaking. Ries,[a] from a consideration of several hundred analyses of brick clays, finds that the silica percentages range from 34 to nearly 91 per cent, with an average of about 59 per cent. The Penobscot Bay specimens are only slightly above this average. The percentage of iron is fairly constant and is sufficient to give the burned bricks a bright-red color. The average for brick clays is about 5 per cent. The absence of calcium carbonate, shown by the absence of CO_2 in analyses 1 and 2, is a desirable feature, as is also the rather high percentage of alkalies. The latter are the most important fluxing constituents of the clay, and on burning serve to bind the grains together. If, as in this case, their quantity is large, the brick may be burned at a lower temperature than otherwise.

Future utilization in brickmaking.—In the opinion of the writer the high quality of these clays, their abundance, and their favorable situation on the seaboard, warrant a much more extensive commercial development. A factor worthy of consideration in this connection is the possibility of utilizing in brick manufacture some of the water power of the coastal region. At a number of places along this part of the coast long tidal estuaries penetrate inland for considerable distances and are usually much contracted in width at one or more places. Through these narrow portions the tide, both at ebb and at flow, surges with great power, which, if harnessed, could be made to serve a variety of useful purposes. It is along such estuaries that the marine clays are best developed, and the possibility of the application of such power in the manufacture of brick, especially of pressed brick, naturally suggests itself. A good example is the case of Weskeag River, with narrows at the village of South Thomaston (4 miles south of Rockland). There has recently been some talk of utilizing the power at this point. Marine clays of fine and uniform texture occur abundantly in this vicinity, the clay of analysis No. 2 being taken from Hayden Point, only 1 mile distant.

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[a] Ries, Heinrich, The clays and clay industry of New Jersey: Final rept. State geologist New Jersey, vol. 6, p. 55.

Possible utilization in the manufacture of Portland cement.—The lime industry of the Rockland region is discussed by the writer in another part of this bulletin (pp. 393–400), and it is worth considering whether the marine clays may not be utilized with this limestone in the manufacture of Portland cement. These cements are artificial mixtures whose essential constituents are lime, silica, and alumina. The first is generally supplied by limestone or marl, the other two by clay. In burning, the three constituents unite to form complex silicates, and it is essential that they be combined in the proper proportions in order to give the best results.

In clays utilized in the manufacture of Portland cement the silica percentage should lie between 60 and 70 per cent. These clays show 62 to 63 per cent silica. According to Eckel, "the alumina and iron oxide together should not amount to more than one-half the percentage of silica, and the composition will usually be better the nearer the ratio $Al_2O_3+Fe_2O_3=\frac{SiO_2}{3}$."[a] In the clay from Hayden Point (No. 2 in the table) this ratio is $\frac{SiO_2}{2.7}$. In reference to the quantity of clay needed Eckel[b] estimates that there should be in sight at least 1,600,000 cubic feet of clays, a twenty years' supply. This would mean only 3.67 acres excavated to the moderate depth of 10 feet. In view of what has been said of the extent and depth of the clays there should be no doubt as to the adequacy of the supply.

The limestone used should be relatively free from magnesia. Lime made from a highly magnesian limestone has the property of setting under water to a very hard mass. When mixed with clay, however, and burned at high temperatures in a Portland cement, it gives cements of doubtful character. The reason for this is that the carbonate of magnesia, unlike the carbonate of lime, does not ordinarily combine with silica or alumina at the clinkering heat employed in the manufacture of Portland cement. In amounts of less than 4 or 5 per cent, however, magnesia is certainly not injurious. The so-called "soft rock" of this region, being poorest in magnesia, would be the most available for cement purposes. As regards quantity needed, Eckel[b] estimates that at least 3,800,000 cubic feet should be in sight for each kiln established, a twenty years' supply. This would correspond to a vein of rock 100 feet wide, 100 feet deep, and 380 feet long. The amount of limestone in the region is probably adequate to meet these demands.

At present the nearest Portland-cement works are located in the eastern part of New York State, and the opportunities for building up a good local cement market seem to be good. With the same advantages of easy and cheap shipment by water, there seems to be no reason why Rockland cement, like Rockland lime, should not be able to hold its own in the New York market, as well as at other points on the Atlantic coast. In this connection it may be borne in mind that nowhere on this coast south of Rockland do pure low-magnesia limestones occur near the seaboard.

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[a] Eckel. E. C., Cements, Limes, and Plasters, 1905, p. 354.
[b] Op. cit., p. 305.

CLAYS OF CAPE COD, MASSACHUSETTS.

By **Myron L. Fuller.**

INTRODUCTION.

Area treated.—In the present paper Cape Cod is considered as synonymous with Barnstable County, all the land south and east of Monument River, which lacks only a mile or two of reaching from Massachusetts Bay to Buzzards Bay, being included under the term. One or two clay localities lying a short distance outside of the limits thus defined are, however, mentioned.

General distribution of the clays.—Although the clays have been worked at relatively few points on the cape, they underlie a considerable portion of the area and are exposed at the surface at a large number of points, especially on the outer arm from Highland Light, Truro, to Orleans and Chatham. Westward from these two villages the clays are less accessible, though still encountered in shallow wells and occasionally exposed in the lower valleys along the south shore and in the bluffs and along the edges of the marshes on the north shore. At West Barnstable, however, a good exposure, worked many years for brick clays, is found. In the highlands, marked by the morainal ridge and sandy-wash plains lying between the north and south shores of this part of the cape and east of Buzzards Bay, the clays are too deep beneath the surface to ever be economically available. Along the shore of Buzzards Bay no important clays have yet been found, and it is probable that they are here below sea level.

Field work.—The data relating to the Cape Cod clays were collected in connection with a study of the Pleistocene geology and artesian water resources of southeastern New England. As a part of this investigation it became necessary to trace out the clay beds of the region, during which abundant opportunity to note their economic aspects was presented. The study was made in 1904 and 1905, and during the latter year the writer had associated with him Mr. F. G. Clapp, to whom credit for a material portion of the facts is due.

GEOLOGY.

General features.—Cape Cod is composed entirely of clay, sand, and gravel, with occasionally a bed of till, consisting of a heterogeneous mixture of clay, sand, and bowlders, often known locally as hardpan, and a superficial deposit of scattered bowlders, sometimes of large size. Bed rock is not encountered anywhere on the cape, but is relatively close to the surface near the head of Buzzards Bay, where wells about Onset are said to have encountered it at a depth of from 60 to 100 feet.

Superficially, the backbone of the cape, except the outer arm, appears morainal. Starting at Woods Hole and extending northward along the shore of Buzzards Bay to Monument River is a hummocky and frequently bowlder-covered ridge, with here and there an undrained depression or kettle, often containing a pond of more or less size. Near Monument River the ridge bends at a somewhat sharp angle to the southeast, following the shore of Cape Cod Bay to the vicinity of Orleans, where it crosses the outer arm and is cut off by the sea. To the east of the Buzzards Bay portion and to the south of the remainder of the ridge lies a great flat sandy-wash plain sloping gently to the sea. North of Orleans the outer arm consists superficially at least of fine gravels and sandy plains, which are horizontally stratified in Eastham, but are more irregular in structure and surface topography in the Wellfleet and Truro regions. At the end of the cape, in the vicinity of Provincetown, nothing but sands thrown up by the waves or piled up by the winds as dunes are to be seen.

Geologic section of the Cape Cod region.

System.	Series.	Stage.[a]	Formations, etc.	Character of deposits.
Quaternary.	Recent.	Recent.	Recent deposits.	Salt and fresh water marsh deposits, dunes, sand bars, and spits.
	Pleistocene.	Wisconsin (Glacial).	Wisconsin drift.	Morainal deposits and outwash gravels and sands.
		Peorian (Inter-Glacial).	Not recognized. Probably represented by a long erosion period, with land elevated.	No deposits recognized on Cape Cod.
		Iowan (Glacial).		
		Sangamon (Inter-Glacial).		
		Illinoian (Glacial).	Unnamed.	Sands and gravels with granite pebbles.
			Montauk drift.	A till made up of brownish, greenish, or gray sandy clay with pebbles and occasional bowlders. Formed by reworking of Gardiner clay and older gravels by ice sheet.
			Herod gravel (often cut out by ice erosion).	Sands and gravels with granite pebbles.
		Yarmouth (Inter-Glacial).	Jacob sand (sometimes cut out by ice erosion).	Yellowish, greenish, and brownish sandy clays or clayey sands, alternating with fine gray to buff sands.
			Gardiner clay.	Light to dark gray nearly black clay, weathering to a greenish or brownish color.
		Kansan (Glacial).	Jameco gravel.	Sands and gravels with granite pebbles.
		Aftonian.	Unconformity of erosion.	Deposits are below sea level in Cape Cod region.
		Sub-Aftonian.	Mannetto gravel.	Sand and gravels, largely quartz, but with a few decomposed granitic pebbles. Below sea level in Cape Cod region.
Cretaceous.			White or yellowish quartz sands and gravels, with clays of white, gray, and various other colors. Below sea level in the Cape Cod region.	

[a] Correlations are provisional, and are based on similarity of succession and history of the Glacial deposits of the Long Island and interior regions.

Character of the deposits.—Until recently all the materials of the cape have been considered to have been deposited in connection with the ice which covered the region in the last or Wisconsin glacial stage. It is now known, however, that these Wisconsin deposits, including those of the moraine and outwash plain, are relatively thin and superficial, the mass of the materials being made up of a complex succession of beds of different types, most of which are far older than those of the last ice invasion. These deposits, which belong to a series extending from New York Harbor eastward to the locality under discussion, have been carefully studied on Long Island, New York, and at other points along the coast, and their sequence has been determined. The succession and character of those which occur above sea level or which approach close to that level on the cape are shown in the foregoing table.

OCCURRENCE OF THE CLAYS.

From the foregoing table it will be seen that there are four clays represented in the materials making up Cape Cod. Only the Gardiner clay and the clayey phases of the Jacob and Montauk formations, however, are known to occur above sea level, hence it is with them alone that the present discussion deals. The thick Cretaceous clays which are the foundation for many of the great clay industries of New Jersey and elsewhere are unfortunately, so far as known, below sea level on Cape Cod. They are probably less than 50 feet below tide level at Highland Light, to judge from the low horizon of the glacial deposits exposed at the base of the bluff, and it is possible that they rise above sea level in the inland portion of the cape in the North Truro region, possibly even appearing near the bottom of the deeper valleys, although no such clays have yet been reported.

COMPOSITION AND STRUCTURE OF THE CLAYS,

Character of the Gardiner clay.—The best exposure of the Gardiner clay is in the bluff at Highland Light, Truro, where it has a thickness of about 40 feet. It is a very tough, not very plastic clay, varying from dark gray to dull black in color. The latter variety is most frequently seen in the lower part of the bed and the lighter gray variety in the upper part. The top is sometimes colored a dull grayish to greenish brown, this being due, it is thought, to the action of percolating waters passing along the contact of the clay at the base of the loose overlying sands. The whole is minutely laminated, although this structure is not always clearly visible except on exposed edges etched out by the atmosphere. The lighter-colored types of clay may show a distinct though not strongly developed shaly structure, apparently due to the presence of thin laminæ of very fine sand. An occasional quartz pebble up to one-fourth inch or so in diameter may occur, but no granitic pebbles or layers of quartz pebbles have been seen. The clay does not appear to contain much true kaolin, being rather a quartz flour. No fossils, lignite, or other traces of organic life have been seen.

The Highland Light deposit may be taken as a type of the Gardiner clay in this region. Nowhere else, however, does it attain such a development, being ordinarily much thinner, the thickness being perhaps as low as 5 feet in some places, while in others the clay may even have been entirely removed by the Montauk ice. Its character is fairly constant throughout the region, although, because of local conditions more favorable to weathering, the brown phase is often more conspicuous than at Highland Light. In the bluff sections, where it has been longer exposed to the action of the weather, the clay often appears structureless and may crumble into the small pellets described in other parts of the country as "buckshot."

Character of the clays of the Jacob formation.—In most localities where the Gardiner clay is exposed, and intervening between it and the coarser materials of the Herod formation, are transitional beds of fine material varying from sandy clays to clayey sands. The more clayey phases approach the clays of the Gardiner in composition, the only difference being the presence of a larger percentage of sandy laminæ. At other times the Jacob is much coarser, in which case the contact with the Gardiner clays is quite definite. In color the clays of the Jacob formation vary from brown and greenish in the more clayey varieties to gray and yellowish in the sandy types.

Character of the clays of the Montauk drift.—Under this head is included the clayey and nearly pebble-free phases of the Montauk drift, which owe their origin to the reworking practically in situ of the Gardiner clay by the Montauk ice sheet. It differs from the unaltered clays in the absence of the minute but highly perfect and regular lamination characteristic of the latter, exhibiting rather an irregular and somewhat indefinite banding, such as might be expected to result from accumulation beneath an ice sheet. The most conspicuous point of difference, however, is the presence of granitic pebbles, either isolated or in layers or pockets, or of an occasional erratic bowlder, indicating a glacial origin in contradistinction to the interglacial origin of the Gardiner clay.

DESCRIPTIONS OF THE CLAYS BY LOCALITIES.

Provincetown region.—West of the bluffs terminating the highland northwest of North Truro the cape is made up of a series of curving wave-built spits which have become connected into a solid mass now covered with dunes rising to heights of from 80 to 100 feet above sea level. Except for the vegetable muck about the marshes and thin beds of mucky silts in the ponds between the sand hills, nothing in the shape of clay is found near the surface in the Provincetown region. The Gardiner clay, as well as the underlying Cretaceous beds, which doubtless include more or less clay, probably once extended over this region, but were subsequently eroded by the agency of waves and shore currents to a depth, according to a recent well boring, of at least 100 feet below the present sea level, before the waves and winds built up the bars, beaches, and dunes constituting the present surface. At a depth of 140 feet a gray clay was encountered which, though probably Cretaceous, somewhat resembles the Gardiner. It is said to be of considerable thickness, but no accurate figures were obtainable.

Truro region.—This term as here used includes the highlands extending northward from Pamet River to the northwest end of the bluff near Moon Pond. The best exposures of clay are found in the bluff near Highland Light, but impure clays or clayey sands occur at a considerable number of other points.

The clay near Highland Light, which is of the typical Gardiner type, first appears at the top of the bluff at a point about one-half mile north of the light-house. It continues along the top for some distance, then gradually sinks as the gentle southward dip brings it nearer the beach. At Highland Light the section shown by the bluff is as follows:

Section at Highland Light, Cape Cod.

	Feet.
Dune sand	5
Yellowish quartz sand, with erratic pebbles near the surface	35
Tough gray to nearly black Gardiner clay, interstratified with sand near top	45
Iron-stained gravel, sometimes partly cemented	15
White sand	15

Beyond the light-house the clay continues with the same southward dip, outcropping with slight undulations for about half a mile, beyond which it is not seen because of the covering of sandy talus for a distance of a mile. At this point about 20 feet of clay are exposed, the top being 40 feet above the beach. It is not seen again to the south, but as the upper part of the bluffs is entirely of sand it is evident that the clay sinks below sea level in this direction. The clay also comes close to the surface on the flats near the highway west of the light-house, where it is reported to be found over a considerable area. Although the clay occurs in vast quantities and is easily accessible from the land side, no material use of it appears to have been made. Similar clays, however, were elsewhere extensively used in the construction of the State roads, and the clays near Highland Light might be used to advantage for similar purposes. Owing to exposure to the open sea it will probably never be practicable to work the clays from the ocean side. It is not impossible, however, that at some future time, when more accessible deposits elsewhere are exhausted, the clays under discussion may be worked with profit if connection by tramway or otherwise is made with the inner side of the cape, from which shipments could be made by vessel. It is certain that in thickness, quality, and extent the clays at Truro outrank any of the clays elsewhere exposed on Cape Cod. Occurring as they do, at the top of a bluff, the pits could be readily drained and the cost of stripping would not be excessive, except in the region south of the light-house, where the beds, owing to the southward dip, are overlain by a considerable thickness of sands and gravel.

Along the beach from the point at which the clay bed described disappears little but sand is seen in the bluffs until a point about 1½ miles northwest of the Pamet River life-saving station is reached. At this point a gray to yellowish-brown laminated sandy clay or clayey sand, associated with numerous springs, shows above the beach. It is much disturbed, and detached fragments up to 10 feet in length occur in lumps upon the beach. Outcrops of upturned clays, or possibly large clay "bowlders," show through the sands of the beach between high and low tide level for some distance. The material seems to represent the transition between the Gardiner clay and the Jacob sands. One-fourth mile farther south a few feet of very fine, compact, and somewhat contorted sandy clay of a greenish color, interlaminated with sand, were seen. This clayey sand or sandy clay continues to show along the beach southward for about one-eighth mile, when it again disappears beneath the beach, only to reappear for a short distance about half a mile farther on, or three-fourths of a mile from the life-saving station. The material does not belong to the Gardiner clay, but rather to the Jacob sands, and, although some portions may contain a sufficient amount of true clay for the material to be utilized for brickmaking, very little of the deposit as a whole could be so used.

In front of the life-saving station a greenish and olive clay, full of iron laminæ and concretions, outcrops in the beach between high and low tide mark. It seems most probable that it is associated with the peat which is being undermined by the waves as they cut back into the extension of Pamet River Valley and that it is of post-Wisconsin origin.

No complete traverse of the west coast of the Truro district was made. The gray to orange sandy clay, however, was seen in the bluff about a mile northwest of North Truro, but the bed was only about 2 feet thick. Some sandy clays or clayey sands were also seen in the bluffs 2 miles south of North Truro. Neither of these clays will prove of economic value unless it is for use on roads or other local purposes.

Wellfleet region.—This region includes the high rolling land from South Wellfleet northward to Pamet River, in the southern part of Truro Township. In the work in this district the beaches on both the ocean and the bay side were traversed and all localities which inquiry showed to contain clays were visited.

Southward along the coast from the Pamet River life-saving station clays are first exposed in the bluff about one-fourth mile distant, where a few feet of clay project through the talus at a single point. The clay shows again about one-half mile south of the station, but it is not until a point 1½ miles south is reached that the clay is seen in any considerable amounts. Here, however, nearly 20 feet of clay are exposed along the bluff for some distance. It is of the dark blue-gray type characteristic of the Gardiner clay, but has thin layers of yellowish sand. It seems to be moderately folded and is overlain by 20 to 30 feet of stratified sand and gravel. A few hundred feet farther on the clay dips nearly or quite to beach level, but soon rises again and is seen through the talus at scattered points for about one-fourth mile, beyond which it is again well exposed as a horizontal bed 20 feet thick at the bottom of the bluff at numerous points for another half mile, south of which it is covered by talus. It appears to sink below the level of the sea at a point northeast of Long Pond, but is strongly developed again one-half mile farther south, where it occurs as a strongly folded bed overlain by from 10 to 30 feet of sands and gravels. South of this point talus prevents the clay from being seen; it probably, however, sinks rapidly and goes below sea level, not reappearing anywhere north of South Wellfleet. In addition to the Gardiner clay there are a number of thin beds of sandy clay a foot or two in thickness interstratified with the sands and gravels constituting the bluffs.

The clay, although present in large amounts, can not be readily worked, owing to the thick covering of sand and gravels. The depressions which occur in the bluff from time to time are due to folding, and the clay is little if any nearer the surface in the valleys than in the ridges. The exposure to the open Atlantic will probably always prevent the working of the clays from this side of the cape.

On the bay side of the cape no clay was seen in the bluffs from Pamet River south to Great Beach Hill. On the east side of Great Beach Hill and on the mainland north of Great Island the talus is somewhat darkened, possibly indicating clay beneath the surface. On Indian Neck, south of Wellfleet, and in the bluff on the small point between the neck and the railroad, exposures of clay or clayey sand are found. In the southeastern portion of the bluffs at Indian Neck from 4 to 5 feet of interstratified sand and clay are exposed along the beach for several hundred feet. This probably belongs to the Jacob formation, but it is said that blue clay, presumably Gardiner, was dug from the beach for use on the State road. In the northern bluff at Indian Neck from 6 to 10 feet of blue clay, overlain by fine brown and gray sands, outcrop in an undulating layer for several hundred feet. It is believed that this clay layer belongs to the Gardiner formation, while the overlying sand is Jacob. The clay is blue, somewhat shaly, and jointed. The same or another layer of the Gardiner clay comes near the surface in the fields back of the hill, where a number of pits were opened and considerable clay was taken out during the building of the State road. On the small point mentioned as occurring between Indian Neck and the railroad, a small bed of clay is exposed in a broad arch in the bluff, but the clay here is not reported to have been worked. In the interior of this part of the cape near the level of the swamp, 1 mile north of Wellfleet, clay was seen in a local pit from which material for the State road had been taken. Another pit which has yielded considerable quantities of clay is located on the north side of the same swamp a little over one-fourth mile to the west. Again, on the south side of the swamp, about one-half mile northwest of Wellfleet, there is a pit 20 feet in depth in which 8 feet of brownish clay, becoming greenish toward the bottom, interlaminated with sand, and carrying occasional granite pebbles, are exposed under 2 or 3 feet of Wisconsin till and gravel. Blue clay is said to have been taken out below the portion of the pit now exposed. The pebble content of the clay is believed to indicate that it belongs to the Montauk drift, though doubtless derived from closely adjacent masses of Gardiner clay. Just south of the road leading from Wellfleet Center westward across the railroad there is another pit of similar clay. Clay occurring in alternate streaks of blue, yellow, and brown, with some sand, is also said to outcrop in the woods one-half mile southeast of North Wellfleet. Pilgrim Spring, emerging from the base of the bluff, just east of Indian Neck, may flow from the top of a similar clay layer.

Eastham region.—The Eastham region includes the area between South Wellfleet on the north and Eastham station on the south. The region is mainly one of flat plains, with the exception of the southern portion, which has a rolling topography. A traverse of the beach from South Wellfleet to the end of the bluffs 1¼ miles south of Nauset Beacons failed to show clay, except in the vicinity of the beacons. A little south of this point a small knob about 10 feet in height of bluish Gardiner clay and brown Jacob sands shows in the face of the bluff. Just beyond several feet of folded gray to light-chocolate Gardiner clay outcrop for 100 feet or so along the beach. The clay as here exposed is too thin and would require too much stripping to be of economic value except for local purposes. South of these outcrops no clay appears in the bluffs, although the Montauk drift is at points quite clayey. No clays were found on the bay side of the cape, except near the south side of the mouth of Blackfish Creek southwest of South Wellfleet. At this point a hard blue putty clay without pebbles was found below tide level and was excavated to a depth of 4 feet for use on the State road. It probably belongs to the Gardiner formation. In general the clay is not to be expected above sea level in the Eastham region.

Orleans region.—Under this head is included the area south from Eastham station to Pleasant Bay, Chatham, and west to the vicinity of Brewster. Throughout most of the area the Gardiner clay seems to be below sea level. Three-fourths of a mile east of Tonset, on the shores of Nauset Harbor, however, 6 or 8 feet of brownish buff sandy clay, either Jacob or Gardiner, are exposed just above beach level. There are also indications of the presence of clay in the hills northwest of Town Cove. Again, 1 mile northeast of Brewster a little sandy clay shows in the beach. Clay is also reported to have been found along the shore near East Brewster. None of the localities, so far as known, are capable of furnishing clay except in very small quantities, and unless other deposits are found no commercial developments are to be anticipated.

Chatham region.—This term is applied to the area included in Chatham and that part of Orleans Township bordering on Pleasant Bay. The area is characterized by a strong development of the Gardiner clays, especially along the shores of the bay mentioned.

One-fourth mile east of the highway, on the north side of Pleasant Bay, a dark clay, presumably the Gardiner, outcrops in a broad, low arch or anticline beneath a thick series of sands and gravels. The clay continues for 100 or 200 feet, then sinks below the beach. In a bluff on the point just beyond the small inlet, one-half mile from the road mentioned, there is another similar anticline of dark Gardiner clay. This is somewhat higher and broader than the preceding, and more clay is exposed. Either of the outcrops could be made to furnish clay for local use without great expense, although considerable stripping would be necessary if the clays were to be worked on a large scale. The most important outcrops of the clays are on Nickersons Neck, on the south shore of Pleasant Bay, beginning about one-third mile from the mouth of Muddy Creek and extending to the bend of the neck, three-fourths mile northeast. The clays outcrop along the beach in a series of gentle folds. From 5 to 30 feet of clay are exposed, all of which could be used for making brick, or similar purposes. The clay, in its lower and less altered portions, is gray to nearly black, but in the upper weathered portions it is greenish or brownish, and weathers into a loose, buckshot-like mass. Thin, ferruginous laminæ and soft iron concretions are abundant in the upper portion. The clay at some points contains a few erratic pebbles, and is elsewhere somewhat sheared, probably owing to the drag caused by the overriding of the Gardiner clay by the Montauk ice, from which the pebbles were also derived. Over the clay there is 30 feet or more of sand and fine gravel, which would make stripping expensive if the clay should ever be worked on a large scale. Amounts sufficient to supply all local needs could, however, be taken from the bluffs with little or no stripping. The islands off the mouth of Pleasant Bay were not visited, but Simpson Island shows rather dark bluffs, which may indicate the presence of clay. The small island southeast of this shows, so far as could be determined from the shore, only gravel. Strong Island, to judge from its elevation, probably contains clay, although it may be entirely covered by sand. On the south side of Nickersons Neck clay is exposed in the high bluff on the north shore of Crows Pond and in a pit just southeast of the highway leading to Nickersons Neck, and near the head of Riders Cove, there is a pit 75 feet in diameter and 15 feet deep, from which considerable clay has been taken in the past. The clay is brown and weathers into small plates or buckshot lumps. It evidently belongs to the upper weathered portion of the Gardiner clay, and agrees very closely in character with the upper portion of the clays in the bluffs on the north side of the neck. Another clay pit is located just west of the State road, as it descends from Nickersons Neck to Riders Cove. The clay varies from light blue and gray in the unweathered portions to brown in the weathered portions, and is very hard and much jointed, as well as folded and sheared. The clay contains a few pebbles, and one bowlder 15 inches in diameter was seen, which would indicate that it is to be referred to the Montauk drift, although doubtless formed from the reworking of Gardiner clay in the immediate vicinity. It bears a somewhat close resemblance to the clay at the brickyards at West Barnstable. Indications of clay were seen on the east side of Riders Cove and near Chathamport. At North Chatham a small pit north of the road shows 5 feet of brownish clays, with occasional pebbles. The same clay rises and shows in the road near by 25 feet higher. It is evidently to be referred to the Montauk drift. No clay was seen in the immediate vicinity of Chatham, and in general it is not to be expected in large quantities, as the region has not been lifted enough to bring the clays above sea level.

Blue clay is, however, reported in considerable amounts near Mill Pond, and near Oyster Pond there is said to be so much brown clay that wells are driven with difficulty. It is not improbable that a few feet of clay may also show above tide level at other points. The clay is not infrequently encountered in the wells.

Harwich region.—The clays in Harwich Township do not appear to occur above sea level in any amount, and only one pit was found in the region, this being in the valley, about three-fourths of a mile west of South Harwich. Inquiry in regard to wells, however, showed that the clays are encountered in many of the wells, and it is said that they can be found at depths of from 6 to 8 feet in some of the hollows. The clay is said to be blue in color and to be extra hard. A very dark reddish clayey sand was seen on the road in the vicinity of Pleasant Lake station, but its source could not be located. Local beds of clayey sand are encountered in the pits at many of the cranberry bogs in this vicinity, but the Gardiner clay has apparently not been found.

Dennis region.—This region is practically coextensive with Dennis Township. It includes the area between Bass River on the west and Harwich on the east, and from Nantucket Sound on the south to Cape Cod Bay on the north. In general, relatively little clay is found, but in one or two localities clay beds are fairly well developed. It is reported that in the vicinity of North Dennis yellow clay, with some erratic pebbles, is encountered below a few feet of gravel or till. The clay is thin and is underlain by a sand layer, below which another layer of blue clay is encountered. The wells, which are from 10 to 35 feet deep, are said to seldom encounter the blue clay. The yellow clay is probably to be referred to the Jacob sand.

At Corporation Landing, on Nobscusset Point, a greenish-gray clay, with pebbles and interstratified sand, is seen in thin layers. A little farther west a greenish-gray sandy clay with ferruginous laminæ comes up above the beach, several feet being exposed for some distance along the beach to the west. At the edge of the marsh, just back of the old wharf, a pit shows 5 feet of gray and greenish clay, with pebbles, presumably Montauk drift, formed by the reworking of the Gardiner clay.

In the vicinity of West Brewster, and to the northeast and southwest, indications of clay are seen in the roadside exposures. Pebbles are generally present, and the clay is most likely a phase of the till. A little blue clay is said to be found in digging for sand at the bogs near West Brewster, but it is not encountered in the wells.

Half a mile southeast of South Dennis, in the bottom of a large gravel and sand pit, is exposed a series of alternating sand and clay layers, becoming bluish at a depth of a few feet. The blue clay is without pebbles, and may represent the Gardiner clay. No clay is encountered in the sand pits at the cranberry bogs in this vicinity, but blue clay is struck in the wells, which are 20 feet or more in depth.

So far as known, the only clay bed worked is that in the pit near South Dennis. Probably none of the clays near West Brewster will yield material of any value except for local use on the roads. At Nobscusset Point and vicinity the clays have been worked in the past, and may possibly be worked again in the future, although over most of the area considerable stripping would be necessary.

Barnstable region.—The area included under this head is practically coextensive with Barnstable Township. At Barnstable blue clay is reported at a depth of 10 to 12 feet in the wells at Finney's store and elsewhere. It is said to form the bottom of the marsh to the north. Traces of clay were seen slightly above marsh level at Calves Pasture Point, northwest of the village. The well water in the vicinity of Barnstable is found on top of the clay. At Harbor Bluff, near Hyannis, there are 5 feet of buff to brown laminated sandy clay, with pockets of sand and small pebbles. It is very tough, and has been worked a little for local purposes at a point where it shows at the surface. It probably belongs to the Montauk formation. No other clay is known in the vicinity. At Hyannis Port clay is said to occur in several of the wells, but it does not appear to reach the surface. Similar conditions exist at Craigville, Centerville, and Osterville. At Cotuit, or Cotuit Port, no clay is known.

Near West Barnstable the only clay deposit which has so far been worked on a considerable scale is located. The pit is about three-fourths of a mile east of the railroad station, at a point where the railroad cuts through a low hill. The clay is quite soft and plastic, and near the surface is of a yellowish color, with a slightly greenish tinge. It is interbedded with lenses of sand and layers of cobbles, and contains throughout the 12 feet exposed in the pit a considerable number of small erratic bowlders, indicating that it probably belongs to the Montauk drift. Toward the bottom of the pit the clay is more bluish, and it is said that a test hole was sunk for a distance of 20 feet through similar material. The clays have been somewhat folded by the ice which has passed over them since their deposition. Stratification is not indicated other than by the sand and bowlder layers mentioned. North of the railroad the clay is said to be of deeper-blue color and to give bricks of a much darker shade. All of the clay is somewhat sandy, but additional sand has to be added in brickmaking.

The clay is reported in the wells in the vicinity of West Barnstable at various depths, apparently having a very irregular surface.

Sandwich region.—An old clay pit is located near the end of Town Neck, northeast of Sandwich, but it is now grassed over and no clay is to be seen. Near by is a house built of the brick from this pit. According to well drivers, the clay occurs all along the shore for a mile or so, both northwest and southeast of Sandwich. It is said to have an irregular surface, varying from a few feet above tide to several feet below. The upper few feet of the clay contain pockets of sand, which often yields water under some artesian pressure. Below these sandy layers the solid blue clay is encountered. It is known to be over 20 feet thick, but the bottom has never been reached, so the maximum thickness is unknown. Clay is also said to have been formerly worked at East Sandwich, where plenty of blue clay was found. In general, however, the clay in the Sandwich district is so near tide level that difficulties in draining would be experienced if extensive pits were to be opened. The clay, however, is of good quality and considerable amounts might be obtained with moderate stripping without going much below sea level.

Falmouth region.—The Gardiner clay has not been seen on the mainland in this region. Near Woods Hole, however, clay is encountered in some of the wells, and can sometimes be found under the beach within a few feet of the surface. So far as could be learned, it is usually of a yellowish or light-gray color, and carries pebbles or bowlders, which indicates that it probably belongs to the Montauk drift. Local beds of more or less clayey sands are also encountered in the sand pits at the cranberry bogs. None of the so-called clays, so far as seen, contain a very high percentage of true clay, and none are likely to prove of any economic value. The Elizabeth Islands were not visited, but the Gardiner clay is known to occur on Nonamesset and others of the islands. It is usually of no great thickness, and is commonly buried to a considerable depth by sand and gravel. Because of the small amounts of the clays and the extensive stripping necessary, it will probably not warrant economic development.

Clays in adjacent regions.—Clay is reported at or near water level in the valley of Monument River, but appears never to have been worked. A yellowish clay was once worked for local purposes on Burgess Point, on the east side of Buzzards Bay, near its head, and some very sandy clays, or, more properly, clayey sands, are found in thin layers in some of the sand pits near the cranberry bogs.

The nearest clay outcrop of consequence is at Indian Hill, between Sandwich and Plymouth. The clays at this point are exposed in the bluffs for a considerable distance, and have a thickness of 20 feet or more. In general character the clays most nearly resemble those on Pleasant Bay, at Chatham. The lower and unaltered portion is of the dark-gray to nearly black type, characteristic of the unaltered Gardiner formation, while the upper portions are of the greenish, brownish, and yellowish types, which everywhere characterize the weathered parts of the same formation. A few pebbles occur in the upper portion of the clay, possibly indicating a reworking by the Montauk ice. The clays at this point are overlain by 20 to 30 feet or more of sands and gravels, which would have to be stripped before the clay could be worked to any extent. The remoteness of the point from any town or railroad, and the exposed nature of the coast, would offer considerable obstacles to the economic development of the deposits.

SUMMARY.

At the present time the clays on Cape Cod are worked on a commercial scale only at West Barnstable. The works at this point have been in operation over fifty years, and supply the entire demand for common brick on the cape. There is at present, therefore, little demand in the region for additional clay for brickmaking purposes. The building of the State roads, however, created a temporary demand, which caused a large number of small pits to be opened, and it would be greatly to the advantage of the traveling public if its use were to be extended to the common roads, which are often at present little more than sandy trails through the woods.

Although the only commercial development of clay is at West Barnstable, there are several other points where the conditions, other than accessibility to transportation lines, are equally favorable, and at some time in the future the deposits may become of considerable economic value, especially at Highland Light, Truro, Wellfleet, and Chatham.

NOTES ON CLAYS AND SHALES IN CENTRAL PENNSYLVANIA.[a]

By George H. Ashley.

Area discussed.—The following notes are among those collected during the survey of the Houtzdale, Curwensville, and Punxsutawney quadrangles, lying in southern Clearfield County, southeastern Jefferson County, and northeastern Indiana County, Pa. The region covered includes the well-known Clearfield County flint-clay area.

GENERAL DESCRIPTION.

The rocks outcropping in this district belong in the lower part of the Pennsylvanian series of the Carboniferous. They include, first, the Pottsville formation, composed of the Homewood and Connoquenessing sandstones, between which lies the Mercer group of shales, clays, and coals; second, the Allegheny formation, including the strata between the Brookville and Upper Freeport coals; and, third, the lower half of the Conemaugh formation, which overlies the Upper Freeport coal.

The clay materials of this area consist of flint clay, plastic clay, and shale. Flint clay occurs at four horizons—three in the Allegheny, which appear to be of rather limited distribution and minor importance, and a fourth at the Mercer horizon in the middle of the Pottsville formation. In the Allegheny formation flint clay occurs below the Upper Freeport coal in a position possibly corresponding with that of the well-known Bolivar flint clay. It has been found at a number of points in the Little Mahoning Creek drainage. Flint clay has been noted at the horizon of the Middle Kittanning coal at a number of widely separated points, notably about Westover and near McCartney, in Clearfield County. The Lower Kittanning coal is underlain by Flint clay in the Little Mahoning Creek drainage. The Mercer coal is underlain by flint clay, which at present is the principal bed being mined in Clearfield County. It is present throughout a broad stretch of country, ranging from Grampian eastward down the Susquehanna Valley to Clearfield, up the Clearfield Creek drainage to the south and southeast, and over into the Moshannon Creek drainage around Osceola. It occurs to the north and northeast of the area studied, but notes on those occurrences can not be given at this time.

Plastic clay underlies practically all the coal seams of the Allegheny formation, but the clay underlying the Lower Kittanning coal appears to be the most important, and at the time the examination of this area was made it was the only one being worked. It is mixed with flint clay in the making of fire brick.

Shales are very abundant in the area of these three quadrangles, but in most cases they are very sandy. There are one or two horizons of shale which give promise of being commercially valuable. One of these beds is low in the Conemaugh, occurring just above the Mahoning sandstone, and is especially well developed in northeastern Indiana County and southeastern Jefferson County. The other shale deposit specially noted is between the Upper and Lower Freeport Coals.

In the following description the localities at which flint clay was noted are given, and special emphasis is put on deposits not being worked. In the majority of cases the data consisted simply of the discovery of the flint clay in the washing of the road, and little or no information could be gained of its thickness or character. In the case of the shales the notes are confined to the deposits lying near transportation, which alone can be considered at the present time as of commercial value.

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[a] See sketch map, fig. 11, p. 272.

DISTRIBUTION OF FLINT-CLAY DEPOSITS.

Center County.—The rise of the rocks from Moshannon Creek toward the southeast to the Allegheny Front exposes the horizon of the Mercer clay all along the northwestern flank of the mountains facing the creek. Little is known of the clay in this region, except at Sandy Ridge, where it has long been worked. Here there are about 2 feet 6 inches of flint clay, overlain by from 3 to 6 feet of soft blue clay and underlain by from 1 to 3 feet of soft clay. The exposure here is just at the outcrop. The bed dips below the surface to the northwest and may in the future be mined in that direction by shafts, should prospecting prove it to be present and of workable quality and thickness.

Clearfield County.—From its outcrop on the Allegheny Mountains the Mercer clay is carried below drainage under the Houtzdale syncline, containing the Houtzdale coal basin, but it rises again above drainage on the flanks of the anticline which runs from McCartney to near Wallaceton and beyond. This arch is low at either end, but rises so that the Mercer clay is in the hilltops at an elevation of over 2,000 feet above sea level to the northeast of Burly. It is carried down to the northeast by the sinking of the anticline until it is but little above the railroad between Wallaceton and Bigler at elevations of 1,750 to 1,770 feet. Along the crest of the anticline it is exposed at a large number of points and has been mined in every direction from Burly. In this district it ranges from 6 to 8 feet in thickness and occasionally shows 12 or 15 feet. It is also exposed on the roads northwest of Sanbourn at a number of points. It has been mined extensively in the crest of the hill 2 miles west of Blue Ball and outcrops at several points a similar distance west of Wallaceton. Along the Tyrone and Clearfield branch of the Pennsylvania Railroad, and the Beech Creek division of the New York Central and Hudson River Railroad, it is extensively mined between Wallaceton and Woodland, rising above drainage at Wallaceton. In this district it shows a maximum thickness of 10 or 11 feet, though the portion mined and the average thickness will be much less. In most of the mines it ranges from 2 feet 6 inches to 4 feet. The worked stratum is apt to be irregular both in thickness and in quality. It is often overlain and underlain by impure or soft fire clay. On Clearfield Creek its horizon is above drainage from a little north of Madera to the mouth of the creek. It was not seen south of Faunce in the main valley, but it outcrops on North Branch of Upper Morgan Run. At Faunce the clay has a thickness of about 6 feet, but usually only a part of that is workable. It has been worked again at Chase, where the flint portion of the clay is only 2 or 3 feet thick, the soft, sandy clay being both above and below. At these points the clay occurs about 200 feet above the level of the creek, but descends toward the mouth of Little Clearfield Creek. The clay is below water level under all of the Little Clearfield Creek drainage. It rises from water level at Curwensville, being exposed just above the Buffalo, Rochester and Pittsburg Railroad track directly across from town, though of poor quality. It runs up Little Anderson Creek, Biglers Run, and Anderson Creek and has been opened and worked at a number of points. It also outcrops over quite an area on Hogback Run to the north of Curwensville. In this district it shows a maximum thickness of 18 feet, though most of the operations on it do not mine more than 6 or 8 feet, and often less. At Stronach the "nodular" clay is from a knife-edge to 6 feet thick, and the "block" clay below from 2½ to 7 feet thick. There is usually some black shale between the clay and the overlying Mercer coal. On Anderson Creek the clay is from 2½ to 10 feet thick. On Hogback Run the clay is reported to show locally as much as 8 feet of "nodular" clay overlying 11 feet of "block" clay. In places this changes to as high as 11 feet of "nodular" clay over 7+ feet of "block" clay.

Farther up Susquehanna River it again appears above drainage at the mouth of Porter Run and remains above water level to the sharp bend below Bells Landing. The Mercer horizon rises above Susquehanna River just west of Mahaffey and continues for several miles up the river, but so far as seen this horizon does not yield workable clay in the region about McGees.

In regard to the quality of the clay on the Susquehanna and Roaring Run drainage the best evidence of its excellence is the extensive use that is being made of it. Large mines are in operation west and northwest of Curwensville and along Roaring Run from Woodland to Wallaceton. The clay about Burly and west of Blue Ball is also mined, in a number of cases being hauled by wagon to the railroad.

Flint clay also occurs in this region at what is supposed to be the horizon of the Middle Kittanning coal. It was seen at several points near Westover and a few miles southwest of McCartney. At one opening near Westover the clay measured from 3 to 5 feet. The outcrop near McCartney was noted in the grading of a switch running southwest to a small mine.

Northeastern Indiana County.—Flint clay was noted at a number of points in the northeast corner of Indiana County, though at none of these points could an examination be made to determine either the thickness or quality of the clay. On Little Mahoning Creek flint clay was noted northeast of Richmond, a little north of the old station of Enterprise, associated with what was considered to be the "B" coal. North of Deckers Point it outcrops at several places in the road high up on the ridges, apparently associated with the "E" coal. Southeast of Nashville, on the road toward Gettysburg, is an outcrop near the top of the hill, probably at the horizon of the "E" coal. The clay also occurs a little to the northwest or north of Robertsville within one-half mile of Little Mahoning Creek. Flint clay was again seen near Glen Campbell, on the road from Urey to Ridge along the crest of the hill, and on the south side of Bear Run on the road from Glen Campbell to North Summit

SOFT CLAYS.

As previously stated, practically all the coal beds of the Allegheny formation are underlain by beds of clay, and in most cases the flint clays noted above have soft clays associated with them. Of these clays the bed underlying the "B" coal appears to be of the greatest thickness and probable value. The "B" coal is above drainage along most of the valleys of the area under consideration, except those lying immediately in the center of the synclines. Prospecting would doubtless reveal clays of commercial thickness and quality at the horizon of the other coals, but as a rule the thickness and character of the clays are not revealed in coal mines. Where the thickness of the clay associated with the other coals was determined, it was usually found to be not over 2 feet. The quality of the clay is unknown

SHALES.

The shales of the eastern portion of this region seem to be uniformly sandy, though possibly not too much so for the successful manufacture of brick or tile. In the western part of Clearfield County and the northeastern part of Indiana County there are many places where the shales immediately over the Mahoning sandstone and immediately below the "E" coal appear to be less sandy in character, and they may warrant careful testing or experimental work. A few of the exposures near the railroads may be noted. These shales outcrop between the "D" and "E" coals at a large number of points around Glen Campbell. A short distance east and west of Burnside the shale above the Mahoning sandstone occurs from 100 to 150 feet above the horizon of the "D" coal. The use of these shales for the manufacture of paving bricks is suggested. Similar shales are found over a broad area in the northern part of this county. To the east of Rossiter the shales between the "E" and "D" coals seem promising. Conemaugh shales are well exposed by the grading for the Buffalo, Rochester and Pittsburgh Railway, though these generally seem rather too sandy for most purposes. Somewhat similar sandy shales are being successfully worked at Punxsutawney on a small scale, being made into common, pressed, and paving brick. A somewhat less sandy shale occurs just south of Punxsutawney, about 150 feet above the valley floor.

BENTONITE OF THE LARAMIE BASIN, WYOMING.

By C. E. Siebenthal.

The variety of clay known as "bentonite" occurs in many localities in Wyoming, and various articles[a] describing its occurrence and character have appeared from time to time. These have been freely drawn on in the preparation of the following paper.

PHYSICAL CHARACTERS.

In color the clay, when freshly exposed, varies from a light yellow to a light olive-green with a waxy luster, but assumes a dull cream color on exposure. In freshly uncovered outcrops it appears as a bedded joint clay, the blocks varying from roughly rectangular or conchoidal shape to long slender pieces. The joints are more or less open and occasionally contain crystals and plates of gypsum and sulphate of soda. The clay is very fine grained, no grit being perceptible to the touch and very little when ground between the teeth. Microscopically it is made up of extremely minute, more or less rounded particles of fairly uniform size and apparently of the same mineral nature, with here and there particles of undecomposed labradorite. The clay has a soft unctuous or soapy feel, but it is quite brittle and is easily quarried. It clings strongly to the tongue. In weathering it absorbs a great amount of water and increases much in volume, forming an intumescent reticulated mantle an inch in thickness, which later melts down to a white powder under the effects of rainfall and frost. Mixed with the proper amount of water it is exceedingly plastic and with the addition of more water it becomes a perfect paste. Tests show that it completely absorbs over three times its weight or seven times its volume of water, and twice as much glycerin as diatomaceous earth will absorb.

COMPOSITION.

Bentonite falls under the kaolin group of hydrous silicates of aluminum, as will be seen from the subjoined table of analyses. Its resemblance to ehrenbergite has been pointed out by Knight, while Read considers it a variety of montmorillonite.

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[a] Knight, W. C., Eng. and Min. Jour., vol. 63, 1897, pp. 600-601; vol. 66, 1898, p. 491.
Merrill, George P., Ann. Rept. U. S. Nat. Museum, 1899, pp. 340, 348.
Slosson, E. E., Tenth Ann. Rept. Wyoming College Agric. and Mech., 1900, extract, p. 14.
Read, Thomas T., Eng. and Min. Jour., vol. 76, 1903, pp. 48, 49.
Darton, N. H., Geologic Atlas U. S., folio 107 (Newcastle, Wyo.), 1904, pp. 5, 9.
Merrill, George P., Nonmetallic minerals, 1904, pp. 233, 243.
Fisher, C. A., Bull. U. S. Geol. Survey, No. 260, 1905, pp. 559-563.
Darton, N. H., Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 400.

Analyses of bentonite.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
	Crook County.	Natrona County.	Weston County.	Newcastle.	Taylor.		Linscott.	Cosgriff.		Cassa Mining Co.	
SiO_2	61.08	65.24	63.25	63.25	59.78	58.25	66.5	64.0	64.0	60.18	60.18
Al_2O_3	17.12	15.88	17.62	12.63	15.10	24.70	23.9	22.9	24.0	26.11	26.58
Fe_2O_3	3.17	3.12	3.70	3.70	2.40	2.61	3.1	3.1	3.2		
MgO	1.82	5.34	3.70	3.97	4.14	1.30	1.0	2.0	1.5	2.54	1.01
CaO	2.69		4.12	4.12	.73	1.61	0.5	1.0	.6		0.23
Na_2O	.20									.80	1.23
K_2O				3.55							
SO_3	.88		1.53	1.58							
H_2O		9.17		6.91	16.26	11.00	5.0	7.0	6.7	10.26	10.26
	86.96	98.75	93.92	99.71	98.41	97.47	100.0	100.0	100.0	99.89	99.49
Sp. gr.			2.132		2.180						

I. Analysis by Westfall.
II, III. Analysis by W. C. Knight.
IV. Geologic Atlas U. S., folio 107 (Newcastle).
V. Unknown.
VI. Analysis by H. L. Hodges.
VII-IX. Analysis by John Ogden.
X, XI. Analysis by Thomas T. Read.

USES.

The shipment of bentonite began in 1888, when several carloads were used by eastern firms in the manufacture of hoof packing, a dressing or poultice for the inflamed hoofs of horses. The chief use of the clay so far, however, is to give body and weight in the manufacture of paper, and practically the whole output of the clay for the last few years has been taken by a paper mill in Denver, Colo. Other uses are in antiphlogistine, a proprietary remedial dressing, and as an adulterant in candies and drugs. Though highly plastic it is unsuitable for the manufacture of fire-clay products on account of its low fusibility. It could possibly be used in the manufacture of pottery by mixing with ground feldspar. It is a good retarder for use with the hard cement plasters. Its high absorption of glycerin, as compared with diatomaceous earth, suggests its substitution for the latter in the manufacture of dynamite.

GEOLOGIC OCCURRENCE.

The bentonite deposits of Wyoming vary somewhat in stratigraphic position. In the vicinity of Newcastle one bed occurs near the top of the Niobrara formation, and another in the Graneros shale, the basal formation of the Benton group. In the Bighorn basin the deposits also occur in the Graneros, a short distance below the Mowry submember of that formation. In the Laramie basin the bentonite beds are also in that portion of the Benton corresponding to the Graneros, but they lie a short distance above the Mowry beds. Just above the deposits is a bed of very black shale and in this, at a distance of 15 or 20 feet from the bentonite, are many highly ferruginous septaria. The thickness of the bentonite in the Laramie Basin ranges up to 4 or 5 feet, but in the Bighorn Basin there are beds over 7 feet in thickness and near Newcastle one is reported to have a thickness of 12 feet.

LARAMIE BASIN DEPOSITS.

Taylor's.—This pit was opened in 1888 in the NW. ¼ SE. ¼ sec. 30, T. 22 N., R. 75 W., about one-fourth mile north of Rock Creek station, on the original line of the Union Pacific Railroad, now abandoned. The clay crops out here on the slope of the hillside, with a thickness of 4 to 5 feet, and dips 4° or 5° to the south with the slope of the hill, the bed being thus exposed over several acres. In working the clay pit the top, consisting of a few inches of weathered débris, is stripped off and the clay is loaded into wagons and hauled 6 miles to Wilcox, the nearest railway station. The clay is shipped loose in box cars, either in lumps, as it naturally comes from the pit, or as the fine loose powder which results from the weathering of the clay.

Linscott's.—About 3 miles southeast of Taylor's a pit was opened in 1897 in NW. ¼ sec. 17, T. 21 N., R. 75 W., near the old line of the railroad. About 20 carloads were shipped before the readily accessible supply was exhausted. Another site was opened up in the SE. ¼ NE. ¼ sec. 14, T. 22 N., R. 76 W., on the north side of Rock Creek, from which about 100 carloads have been shipped. The thickness and relations are analogous to those of Taylor's bank.

Cassa Mining Company.—This claim is located in the N. ½ sec. 10, T. 22 N., R. 76 W. Nothing but development work has been done up to the present time, and only sample consignments have been shipped. The claim takes in a strip a mile in length, the occurrence of the clay being similar to those previously described.

Sam White's.—This property lies in the NW. ¼ sec. 20, T. 22 N., R. 77 W., on the south slope of Como Ridge. This occurrence of the clay is similar to the others except that the dip of the rocks is steeper and a smaller area is uncovered. Only development work has been done.

Cosgriff's.—This claim is located in the NW. ¼ sec. 12, T. 21 N., R. 75 W., near the prominent point locally known as Chalk Bluff. The thickness, geologic relations, and quality of the outcrop are the same as in the occurrences already described. No clay has been shipped.

The foregoing comprise all the occurrences of this clay which have assumed commercial importance in the Rock River region, the type locality. They are strung along the outcrop of the Benton formation for a distance of 20 miles. The bed of clay is probably persistent throughout that distance, though its outcrop is not always apparent. Bentonite has been noted in a few localities elsewhere in the Laramie basin.

Hutton Lakes.—Along the bluff on the northwest shore of the northern of the Hutton Lakes for a distance of 200 yards a bed of bentonite makes a white band in the black shale of the Benton formation. This bed is from 3 to 4 feet thick and dips about S. 85° W. The Mowry beds outcrop to the east and evidently dip beneath the clay. The quality is apparently good.

Sand Creek.—Near the middle of the north side of sec. 2, T. 13 N., R. 75 W., in the east bank of Sand Creek, a 4-foot bed of characteristic bentonite is underlain by 20 feet of soft black shale and overlain by fossiliferous sandstone and light and dark shales. The relation of the bentonite to the Mowry beds is not clear, but the probabilities are that this clay is beneath the Mowry.

Riverside.—On the Riverside ranch, in the NE. ¼ sec. 14, T. 13 N., R. 76 W., a bed of much-weathered bentonite less than 2 feet in thickness lies a few feet above the Mowry beds. In the SE. ¼ sec. 6, T. 14 N., R. 75 W., the bed is reported to thicken to 4 feet.

PRODUCTION AND PRICES.

From 1888 to 1895, inclusive, the output of bentonite averaged about 60 tons annually. From that time it gradually increased until in 1902 it is reported to have been 1,200 tons. With the closing down of the western paper mills the output almost stopped, and in 1905 only a very small amount was shipped.

In the early period from 1888 to 1895 the price averaged $25 per ton, f. o. b. cars. The price then dropped to $5, but later rose to $6 and $7 per ton. The total production to date is approximately 6,000 tons, with a value of $45,000.

SURVEY PUBLICATIONS ON CLAYS, FULLER'S EARTH, ETC.

In addition to the papers listed below, references to clays will be found in the publications listed under the head of "Cements," on page 384.

BRANNER, J. C. Bibliography of clays and the ceramic arts. Bulletin No. 143. 114 pp. 1896.

ECKEL, E. C. Stoneware and brick clays of western Tennessee and northwestern Mississippi. In Bulletin No. 213, pp. 382–391. 1903.

FISHER, C. A. The bentonite deposits of Wyoming. In Bulletin No. 260, pp. 559-563. 1905.

GOLDING, W. Flint and feldspar. In Seventeenth Ann. Rept., pt. 3, pp. 838–841. 1896.

HILL, R. T. Clay materials of the United States. In Mineral Resources U. S. for 1891, pp. 474–528. 1892.

——— Clay materials of the United States. In Mineral Resources U. S. for 1892, pp. 712–738. 1893.

LANDES, H. The clay deposits of Washington. In Bulletin No. 260, pp. 550–558. 1905.

RIES, H. Technology of the clay industry. In Sixteenth Ann. Rept., pt. 4, pp. 523–575. 1895.

——— The pottery industry of the United States. In Seventeenth Ann. Rept., pt. 3, pp. 842–880. 1896.

——— The clays of the United States east of the Mississippi River. Professional Paper No. 11. 298 pp. 1903.

SCHRADER. F. C., and HAWORTH, E. Clay industries of the Independence quadrangle, Kansas. In Bulletin No. 260, pp. 546–549. 1905.

SHALER, N. S., WOODWORTH, J. B., and MARBUT, C. F. The glacial brick clays of Rhode Island and southeastern Massachusetts. In Seventeenth Ann. Rept., pt. 1, pp. 957–1004. 1896.

VAUGHAN, T. W. Fuller's earth deposits of Florida and Georgia. In Bulletin No. 213, pp. 392–399. 1903.

WILBER, F. A. Clays of the United States. In Mineral Resources U. S. for 1882, pp. 465–475. 1883.

——— Clays of the United States. In Mineral Resources U. S. for 1883-1884, pp. 676–711. 1885.

WOOLSEY, L. H. Clays of the Ohio Valley in Pennsylvania. In Bulletin No. 225, pp. 463–480. 1904.

BUILDING STONE AND ROAD METAL.

NOTE ON A NEW VARIETY OF MAINE SLATE.

By T. Nelson Dale.

In September, 1905, the writer made a trip with Dr. George Otis Smith, of the United States Geological Survey, and Prof. Leslie A. Lee, State geologist of Maine, to a slate prospect said to have been opened in 1890 in the town of Forks, Somerset County, in central Maine, between Kennebec and Piscataquis rivers.

This prospect lies in the broad belt of Paleozoic slate which Prof. C. H. Hitchcock's geological map of 1885 shows as extending from the Kennebec to Schoodic Lake and beyond, and which includes the slate quarries of Brownville, Monson, and North Blanchard. The location of this slate deposit is about longitude 69° 57′, latitude 45° 16′, or about 18 miles west of the North Blanchard quarries, in the southwest corner of the town of Forks, about 3 miles northeast of Caratunk, over a mile about northwest of the hotel on Pleasant Pond, about half a mile from the Washington Schoolhouse, 1,090 feet above sea level, on Holly Brook, on land owned by Lawrence Hill. The nearest railroad is the Somerset Railway Extension at Mosquito Narrows, 6 miles distant.

The slate crops out in the bed of the brook, being exposed for a thickness of 30 feet or more across the cleavage. The excavation appears to have been from 10 to 15 feet deep. The cleavage strikes N. 55° E. and dips from steep northwest to 90°, but in the upper 10 feet there is a fold resulting in a steep southeast dip. The course of the bedding could not be determined, but the microscopic examination affords indications that it is nearly parallel to the cleavage.

The slate is bluish black, of fine texture and cleavage surface, with a luster not so great as that of the Brownville slate, but yet bright. It is graphitic, contains a very small amount of magnetite, has no argillaceous odor, does not effervesce in cold dilute hydrochloric acid, is quite sonorous, and is readily perforated. Neither the ledge nor the fragments exposed for fifteen years show discoloration.

Under the microscope the section shows a matrix of muscovite (sericite) with a brilliant aggregate polarization, proving it to be a mica-slate. The cleavage is fine and regular. The next conspicuous feature is the presence of about 52 lenses of pyrite to each square millimeter, measuring (in transverse section) from 0.02 to 0.06 mm. in length by 0.004 to 0.016 mm. in width. In sections parallel to the cleavage these lenses have a very irregular outline and are often as broad as long. They account for the limonitic staining on cleavage surfaces of water-soaked specimens. Quartz is abundant but minute. No carbonate could be detected. A few tourmaline prisms up to 0.11 mm. in length occur. Some scales of chlorite with interleaved muscovite measure up to 0.09 mm. Occasional zircon fragments and aggregations of rutile crystals appear.

The constituents of this slate, arranged in the order of their abundance, appear to be muscovite, quartz, chlorite, pyrite, and graphite, with accessory tourmaline, zircon, and rutile.

This slate at Pleasant Pond, the nearest important topographic feature, represents a different quality of black slate from either the Brownville or the Monson slate, having nearly as much luster and nearly as fine a cleavage as the former, yet without its abundance of magnetite, and being without the dull and roughish surface of the Monson slate. It would prove suitable either for roofing or mill-stock purposes.

Another ledge of similar slate has been exposed by trenching, about a third of a mile away, near the road and Mr. Hill's house, but the slate here shows some false cleavage, at least at the surface. Should that feature continue into the mass the slate would have little or no commercial value. This feature was not characteristic of the Holly Brook outcrop.

SURVEY PUBLICATIONS ON BUILDING STONE AND ROAD METAL.

Alden, W. C. The stone industry in the vicinity of Chicago, Ill. In Bulletin No. 213, pp. 357-360. 1903.

Bain, H. F. Notes on Iowa building stones. In Sixteenth Ann. Rept., pt. 4, pp. 500-503. 1895.

Dale, T. Nelson. The slate belt of eastern New York and western Vermont. In Nineteenth Ann. Rept., pt. 3, pp. 153-200. 1899.

——— The slate industry at Slatington, Pa., and Martinsburg, W. Va. In Bulletin No. 213, pp. 361-364. 1903.

——— Notes on Arkansas roofing slates. In Bulletin No. 225, pp. 414-416. 1904.

——— Slate investigations during 1904. In Bulletin No. 260, pp. 486-488. 1905.

——— and others. Slate deposits and slate industry of the United States. In Bull. 275. 1906.

Diller, J. S. Limestone of the Redding district, California. In Bulletin No. 213, p. 365. 1903.

Eckel, E. C. Slate deposits of California and Utah. In Bulletin No. 225, pp. 417-422. 1904.

Hillebrand, W. F. Chemical notes on the composition of the roofing slates of eastern New York and western Vermont. In Nineteenth Ann. Rept., pt. 3, pp. 301-305. 1899.

Hopkins, T. C. The sandstones of western Indiana. In Seventeenth Ann. Rept., pt. 3, pp. 780-787. 1896.

——— Brownstones of Pennsylvania. In Eighteenth Ann. Rept., pt. 5, pp. 1025-1043. 1897.

Hopkins, T. C., and Siebenthal, C. E. The Bedford oolitic limestone of Indiana. In Eighteenth Ann. Rept., pt. 5, pp. 1050-1057. 1897.

Keith, A. Tennessee marbles. In Bulletin No. 213, pp. 366-370. 1903.

Ries, H. The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut. In Seventeenth Ann. Rept., pt. 3, pp. 795-811. 1896.

Shaler, N. S. Preliminary report on the geology of the common roads of the United States. In Fifteenth Ann. Rept., pp. 259-306. 1895.

——— The geology of the road-building stones of Massachusetts, with some consideration of similar materials from other parts of the United States. In Sixteenth Ann. Rept., pt. 2, pp. 277-341. 1895.

Siebenthal, C. E. The Bedford oolitic limestone [Indiana]. In Nineteenth Ann. Rept., pt. 6, pp. 292-296. 1898.

Smith, G. O. The granite industry of the Penobscot Bay district, Maine. In Bulletin No. 260, pp. 489-492. 1905.

GLASS-MAKING MATERIALS.

During the last season several important glass-manufacturing districts have been visited by Survey geologists, and careful investigation has been made of the glass sands and other raw materials used in the manufacture of this product. The results of this work are summarized in the following three reports:

THE REQUIREMENTS OF SAND AND LIMESTONE FOR GLASS MAKING.

By Ernest F. Burchard.

INTRODUCTORY STATEMENT.

The data for the following paper were derived from a brief study of the glass sands of the middle Mississippi basin. Glass manufacture admits of such slight variations in the character of its raw materials that the materials used from the Central States are regarded as representing very fairly the grade demanded for the industry at large. The points considered in this paper are intended mainly to serve as a guide to persons who wish to know whether certain sandstones or limestones may be suitable for glass making. Therefore only the chemical and physical properties are taken up here, and the consideration of other conditions on which the value of a deposit depends is reserved for the paper "Glass sands of the middle Mississippi basin," pages 459–472 of this bulletin.

LITERATURE.

The statistics of the production of glass sand in 1902, 1903, and 1904 have been gathered and compiled by A. T. Coons and published each year by the Survey in "Mineral Resources of the United States." These reports have been freely used in preparing papers for this bulletin. Besides these reports there is not much literature dealing directly with glass sand, but nearly all technical papers or manuals on the subject of glass contain useful data with regard to the sand. Among such technical papers may be mentioned the following:

Weeks, J. D., Glass materials: Mineral Resources U. S. for 1883-84, U. S. Geol. Survey, 1885.

Biser, B. F., Elements of Glass and Glass Making, 1899.

Linton, Robert, Glass Making in the United States: Eng. and Min. Jour., vol. 68, No. 16, 1899, p. 454.

Linton, Robert, Glass: Mineral Industry for 1899, 1900, pp. 234-263.

Gillinder, James, Glass Manufactures in America: Encyclopedia Americana, vol. 8.

Austin, Shirley P., Glass: Twelfth Census of the United States, vol. 9, Manufactures, pt. 3, 1902, pp. 941-1000.

Uhlig, E. C., Chemical Analysis for Glass Makers, 1903.

Grimsley, G. P., Manufacture of glass in Kansas: First biennial report Kansas Bureau of Labor. 1901-2, 1903, pp. 343-346.

DEFINITION AND COMPONENTS OF GLASS.

Glass is a fused mixture of the silicates of alkalies, alkaline earths, and of more common metals. Usually the alkaline bases are sodium and potassium; the alkaline earth is calcium, and the common metallic element is lead. All of these are used in the form of salts. In melting together the various ingredients employed in the batch or mixture it appears that silica under the influence of heat in the presence of a flux forms silicates with sodium or potassium, and calcium, lead, etc., and the alkaline silicate then dissolves the remaining silicates. It is this solution that solidifies into glass on cooling. Glass may be divided into four general classes—plate, window, green bottle, and flint. Owing to manufacturing conditions, few makers follow the same formula, but the following table shows the general proportion by weight which sand bears to the other ingredients commonly used in certain types of American-made glass.[a]

General proportions by weight of various components of glass.

Component.	Plate glass.	Window glass.	Green bottle.	Lead flint.	Lime flint.
Sand (SiO_2)	100	100	100	100	100
Salt cake (Na_2SO_4)		42	38		
Soda ash (Na_2CO_3)	36				36
Limestone ($CaCO_3$)	24	40	34		
Carbon (C)	.75	6	5		
Arsenic (As_2O_3)	1	2		.15	.02
Slaked lime ($Ca(OH)_2$)					12
Potash (K_2CO_3)				34	
Red lead ($2PbO+PbO_2$)				48	
Niter ($NaNO_3$)				6	1
Manganese (MnO_2)				.06	6.66
Antimony (Sb)				.02	.23

REQUIREMENTS OF GLASS SAND.

Sand is therefore the major constituent of glass, constituting from 52 to 65 per cent of the mass of the original mixture, or from 60 to 75 per cent of the finished product after melting has driven off carbon dioxide, sulphur dioxide, and other volatile materials. To the sand is due the absence of color (according to its purity), the transparency, brilliancy, and hardness of glass. In other words, the quality of the glass depends largely on the quality of the sand. For the finest flint ware, such as optical and cut glass, "water whiteness," absolute transparency, great brilliance, and uniform density are required, and only the purest sand can be employed, since slight impurities, especially small quantities of iron, tend to destroy these effects. For plate and window glass, which are commonly pale green, absolute purity is not so essential, but generally the sand should not carry more than two-tenths per cent of ferric oxide. Green and amber glass for bottles, jars, and rough structural work can be made from sand relatively high in impurities. An excess of the chief impurity, iron, is usually avoided in the quarries by a careful selection of the whitest sand, although the whitest sand is not invariably the purest. Repeated washing tends to remove the iron. Magnetic separators also have been resorted to, especially when the iron is present in the form of magnetite. Clay materials are objectionable because they cloud the glass. Washing helps to remove them, since they occur usually in a very finely divided state. Magnesia, which is more apt to be introduced into glass materials through limestone than through sand, is troublesome because it renders the batch less fusible. If the sand is derived from indurated sandstone the latter should be friable or easily crushed. In examining sand, in order to ascertain its value for glass-making purposes, inspection with a magnifying glass is the best preliminary test. The following points should be observed: The sand should be nearly white in color; it should be of medium fineness (passing a 20 to 50 mesh horizontal sieve); the grains should be uniform in size, even, and angular, or, less preferably, they may be rounded. A simple chemical test may be employed by heating the sand in a dilute acid. Effervescence indicates the presence of lime; loss of color shows the presence of clay impurities. Iron in the most minute quantity may be detected by dissolving sand in hydrofluoric acid and adding potassium ferrocyanide, which produces a blue precipitate if iron is present. Complete quantitative analyses as well as a furnace test should be made as a final determination of the character of a prospective glass sand. The impression has long prevailed, especially among writers on the subject of glass making, that round-grained sands are at a decided disadvantage in comparison with the sharp, angular variety. Practice seems to disagree with this idea, at least in the case of the Mississippi Valley plants, where smooth, rounded sand is successfully used for all ordinary varieties of glass and for some fine flint ware. As a rule, no very close check is kept on materials by manufacturers of the ordinary commercial grades of glass. Results are watched with care, however, and experience with certain materials usually determines their use or rejection. Sand uniformly finer than one-sixtieth inch is said to "burn out" in the batch and not to produce as much glass per unit of weight as does coarser sand. In a mixture of coarse and fine sand the finer sand is liable to settle to the bottom of the batch, thus preventing an even mixture of the materials and producing in consequence a glass uneven in texture.

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[a] Data, except for lime flint, are taken from Linton, Robert, Glass: Mineral Industry for 1899, vol 8, 1900, pp. 244-245.

ANALYSES OF GLASS SAND.

The following analyses submitted by the American Window Glass Company show the different qualities of sand used in its glass works:

Analyses of glass sand used by American Window Glass Company.

Constituent.	No. 1.	No. 2.	No. 3.	No. 4.
Silica (SiO_2)	99.990	99.714	99.659	99.579
Alumina (Al_2O_3)	.008	.280	.310	.350
Iron oxide (Fe_2O_3)	Slight trace.	.006	.011	.021
Lime and magnesia (CaO and MgO)	.002	.020	.020	.050
	100.000	100.020	100.000	100.000

No. 1 is suitable for the very highest grades of glassware and flint glass. Nos. 2 and 3 are suitable for tableware, plate glass, chimneys, prescription ware, etc., and No. 4 is used for window glass.

The following analyses are submitted by the Pittsburg Plate Glass Company as samples of sand used by its plants:

Analyses of glass sand used by Pittsburg Plate Glass Company.

Constituent.	No. 1.	No. 2.	No. 3.	No. 4.
Silica (SiO_2)	99.21	98.90	98.95	98.94
Alumina (Al_2O_3)	.30	.20	.50	.30
Volatile matter	.21	.25	.24	.23
Iron oxide (Fe_2O_3)	.003	.002	.0024	.0036
Lime (CaO)	.20	.54	.30	.40
Magnesia (MgO)	Trace.	.20	.10	Trace.
	99.923	100.092	100.0924	99.8736

For sands with analyses comparable with the above, no decolorization is attempted in manufacturing plate glass. Sand containing more iron than is shown in the tables may be used in making green glass bottles and cheap glassware, or, with the addition of decolorizing agents, in making window glass.

Analyses of glass sands mined

Location of mine or quarry.	Operator.	Constituent.		
		Silica (SiO_2).	Magnesia (MgO).	Lime (CaO).
ILLINOIS.				
Ottawa, Lasalle County	Ottawa Silica Co	99.45	Trace.	0.13
South Ottawa, Lasalle County	United States Silica Co	99.89	0.01	.00
Wedron, Lasalle County	Wedron White Sand Co	99.89	.01	.00
Utica, Lasalle County	E. J. Reynolds & Co	99.576	.002	.0197
MISSOURI.				
Klondike, St. Charles County	Tavern Rock Sand Co	99.97		
Grays Summit, Franklin County	White Sand Co. of Missouri.	99.839		
Jefferson County, near Pacific	Missouri Silica Co	99.69	.31	

Physical properties of glass sands,

Locality.	Operator.	Sample.	Color.
Ottawa, Ill	Ottawa Silica Co	Finest grained	Very faint yellow
Do	do	Fine and coarse mixed	White
Do	do	Coarsest grained	do
Do	do	Crude, direct from pit	Grayish white
Utica, Ill	E. J. Reynolds & Co	Crude, from car	Grayish yellow
Klondike, Mo	Tavern Rock Sand Co	Extra quality	White
Do	do	Average quality	Faint pinkish yellow
Do	do	Crude, direct from pit	White
Grays Summit, Mo	White Sand Co. of Missouri.	Finished product	do
Do	do	Crude, from quarry	Very light gray
Pacific, Mo	Pacific White Sand Co	Finished product	Faint pinkish white
Do	Missouri Silica Co	Direct from quarry	Faint yellow
Do	Pacific Glass Sand Co	Prepared for plate glass.	Faint yellowish white
Do	do	Dried, not screened	Faint yellow
Do	do	Crude, mine run	do
Crystal City, Mo	Pittsburg Plate Glass Co	Prepared	do
Do	do	Average mine run	White, with faint yellow lumps.
Berkeley Springs, W. Va.	West Virginia Sand Co	Crushed sandstone, finished product.	Grayish white

in the Mississippi basin.

Constituent.				Authority.
Iron oxide (Fe_2O_3).	Alumina (Al_2O_3).	Other.	Total.	
0.30		....	99.88	Prof. R. E. Lyons, Indiana University, Bloomington, Ind.
Trace.	0.051	....	99.951	R. W. Hunt & Co., Chicago, Ill.
....	.051	....	99.951	Cary & Moore, Chicago, Ill.
.0903	.283	....	99.971	Operators of quarry.
....	.03	....	100.00	Regis Chauvenet & Bro., St. Louis, Mo.
.0014	....	(H_2O), 0.154..	99.9944	John F. Wixford, St. Louis, Mo.
....	....	....	100.00	Regis Chauvenet & Bro., St. Louis, Mo.

mainly from middle Mississippi basin.

Angularity.	Sieve tests (percentages are approximate).				
	Larger than 20 mesh.	Passes 20 mesh.	Passes 40 mesh.	Passes 60 mesh.	Passes 100 mesh.
Very little............	....	100	100	92	25
.....do............	A few grains............	99+	85	18	3
None............	1 per cent............	99	6	1−	0
.....do............	A few grains............	99+	23	3	1−
Very little............	.....do............	99+	45	11	3
.....do............	Small lumps only............	100	90	15	1
.....do............	Fine lumps only............	100	82	17	2
None............	....	100	90	15	1
Very little............	....	100	92	25	2
.....do............	Fine lumps only............	100	88	55	1−
None............	Small lumps only............	100	85	12	2
.....do............	.....do............	100	96	42	2
A little of finest grain......	....	100	99	60	10
None............	Small lumps............	100	90	22	2
Very little............	.....do............	100	85	65	5
.....do............	Less than 1 per cent............	99+	23	13	1
None............	....	100	55	20	1
90 per cent............	....	100	98	25	1−

REQUIREMENTS OF LIMESTONE.

In its connection with sand as a glass material limestone is of interest to quarrymen. As shown in the table on page 453, limestone enters the batch of several kinds of glass to the extent of about 18 per cent of its mass. The rock is crushed, ground finely, and screened. Purity is as essential in limestone as in sand, and it is probable that much of the impurity which finds its way into the batch comes unsuspectedly from the limestone. Limestone, therefore, should be analyzed frequently, as it may carry clay and iron pyrites as well as carbonates of iron and magnesia, all of which are objectionable for reasons previously stated. Moreover, beds in the same quarry often vary in composition within short distances. Limestone of good quality belonging mainly to the Carboniferous system is widely distributed in Illinois, Missouri, Kansas, and other central glass-manufacturing States, and, compared with sand, it brings a high price. Analyses of certain limestones used in this industry are given below, and many suitable limestones are described by Mr. E. C. Eckel in Bulletin No. 243, on the Cement Materials and Industry of the United States.

Analyses of limestone used in glass making.

Locality.	Lime carbonate ($CaCO_3$).	Magnesium carbonate ($MgCO_3$).	Iron oxide (Fe_2O_3).	Alumina (Al_2O_3).	Silicates and silica (SiO_2).
1. Meramec Quarry Co,. Wickes, Mo	90.23	0.0	0.59	....	8.87
2. Meramec Quarry Co., Wickes, Mo	97.96	.18	....	....	1.86
3. Armstrong Quarry, Alton, Ill	97.72	0.0	.20	1.10	1.01
4. Pennsylvania	97.23	1.48	(Fe_2CO_3.) .16	.02	1.01

1. F. P. Mason, analyst.
2. Wm. Chauvenet, analyst.
3. S. E. Swartz, analyst.
4. Min. Industry for 1899, p. 240.

GLASS SAND OF THE MIDDLE MISSISSIPPI BASIN.

By Ernest F. Burchard.

INTRODUCTORY STATEMENT.

A conservative estimate of the value of the glass products manufactured in the United States in 1905 is in round numbers $65,000,000. The cost of material used approximates $18,000,000, and in this the cost of glass sand was somewhat more than $1,000,000, exclusive of freight charges. Within the half century preceding 1900 the value of glass products showed an average increase of 70 per cent for each decade, and the growth is still vigorous. In view of the remarkable development of an industry so largely dependent for its raw materials on mineral deposits, a brief study has been made of the principal sand-producing areas of the middle Mississippi basin and of their relations to manufacturing centers in the same district. Undeveloped sands in Arkansas, Missouri, Kansas, Wisconsin, and Iowa have been examined in connection with geologic surveying in progress in those States. It is hoped that the information published in this and the preceding paper may be of service to owners of land on which deposits of sand are found and to persons engaged in the production or use of glass sand who may wish to know where further supplies of the material may be obtained.

Topographic maps covering the greater part of all the areas mentioned herewith and geologic maps covering a small part of the same have been issued by the survey. Lists of these maps are given in the sections devoted to the respective areas.

In the paper "Requirements of sand and limestone for glass making," pages 452–458 of this bulletin, are outlined those characteristics which render a sand suitable or unsuitable for making glass, and in tabular form data are presented concerning the chemical composition and physical character of several sands at present in successful use. Below are given similar data regarding sands of hitherto unknown or doubtful value.

To the producer the questions of physical conditions affecting quarrying and mining, of the amount of available sand, and of location with respect to transportation routes and to markets are as important as that regarding the quality of the sand. Some details are therefore given in the descriptions of properties which illustrate conditions and limitations of successful operation.

GLASS-MAKING INDUSTRY OF THE REGION.

In connection with the examination of sand plants several representative glass factories were visited. Glass of four general classes—plate, window, green bottle, and flint— is made in the middle Mississippi basin from materials obtained, for the most part, in the region. The majority of the glass factories are grouped into two districts—the St. Louis district and the southeastern Kansas district. Fuel and raw materials are naturally the controlling factors in the location of glass plants, and of the two the proximity of fuel seems to be regarded as the more important. Where coal is the basis of the fuel, if it requires 1 ton of coal to 1 ton of glass, nearly as much coal by weight as raw material has to be transported, yet the freight rates on sand, lime, and salt cake are decidedly higher than on coal for a given distance. Therefore, it is important that plants using coal should also be relatively near a supply of sand. When natural gas in a fresh field is the fuel it is so much cheaper than producer gas made from coal near the mines that the glass can stand the cost of a long haul for sand and other materials if necessary.

St. Louis district.—About eight factories are situated in this district—two at St. Louis, one at Valley Park, and one at Crystal City, Mo., and one each at East St. Louis, Belleville, Alton, and Litchfield, Ill. The factories in St. Louis itself are situated well between the sand, 35 miles or more to the west, and the Illinois coal fields 10 to 15 miles to the east. The other factories range in location from the one situated on the glass sand at Crystal City to the one situated on the coal at Belleville. Producer gas from southern Illinois coal is commonly employed as fuel, although one furnace at Alton is fired direct from coal. Plate glass is made by Pittsburg firms at Crystal City and at Valley Park. The factory at Crystal City has been established about thirty years. Its present capacity is two furnaces of 20 pots each. A new pot house is under construction, and other new buildings of a value of $2,000,000 are under contract. The factory at Valley Park has been erected within the last few years. It contains four furnaces of 20 pots each.

The main products of the other factories are bottles of various grades, certain ones making beer bottles exclusively. The plant at Alton, said to be the largest in the United States, makes bottles of every description, besides miscellaneous articles from both common and flint glass. Eight glass houses are operated at Alton, both the pot and the continuous-tank systems being employed.

Southeastern Kansas district.—The manufacture of glass in the Kansas gas belt was begun less than three years ago. There are now 21 plants in the field, including one just across the line at Bartlesville, Ind. T., all using natural gas for fuel. These glass factories are located as follows: Coffeyville 7, Independence 3, Peru 2, Chanute 2, Altoona 2, Caney, Cherryvale, Neodesha, Fredonia, and Bartlesville 1 each. Many of them have been moved from the waning gas fields of Indiana, attracted by the cheapness and abundance of gas in the new field. Whereas the cost of producer gas or of gas made from oil in the St. Louis district, and in Indiana and Pennsylvania, is from 8 to 12 cents per thousand cubic feet, Kansas manufacturers are paying only 3 cents per thousand for natural gas and some plants are said to obtain it as low as 2 cents. No plate glass is made in this field at present, but practically all the other grades of window glass and all the wares of glass except the finest material for chemical and optical purposes are made.

A run of glass was made in 1903 at the works of the Midland Glass Company at Independence under the direction of Superintendent Thornberg. Kansas materials were used, including sand from the Buxton formation near Fredonia (corresponding to samples 1 and 2, p. 462), limestone from Sedan, and salt cake from the sulphuric-acid works at Argentine. The glass was clear and of high quality, and the character of the materials seemed to be all that could be desired. Interest in the development of this glass sand has been revived recently and it may be opened up if the project can be placed on a practicable basis. At Coffeyville three plants make window glass, and certain of the others make bottles, fruit jars, table ware, and lantern chimneys. All three plants at Independence and the plant at Fredonia make window glass. The plant at Caney makes a variety of wares. That at Cherryvale makes a special feature of tumblers and table ware, using an excellent grade of clear lead-flint glass. At Neodesha flasks and prescription bottles of flint glass are made. Sand is supplied mostly from the belt west of St. Louis, and the freight charges bring the total cost of material per ton to about four times its selling price. A little sand has been imported from the Ottawa, Ill., district at a total cost per ton of nearly eight times its selling price. In regard to limestone supplies the Kansas factories are situated more advantageously. Some crushed limestone has been obtained from neighboring cement mills and considerable is shipped from Sedan. Still it seems to be necessary to import the greater portion of it from Missouri points, Ash Grove being an important center. Salt cake is brought from Argentine, Kans., and the Kansas plants are thus nearer to this important requisite than any others except one located at Kansas City. The first plants erected in southeastern Kansas were pot furnaces, but of the more recent ones nearly all are continuous-tank furnaces. The continuous-tank system, while involving a much greater initial expense, is estimated to increase the output about 40 per cent over that of the pot furnace with the same amount of fuel and labor, besides producing a more uniform quality of glass. At Coffeyville fruit jars are blown with compressed air by a system of automatic blowpipes and molds.

LOCAL PRODUCTION AND METHODS OF PREPARATION OF SAND.

Illinois and Missouri together furnish at present about 350,000 short tons annually, nearly 40 per cent of the total supply of glass sand in the United States. Pennsylvania produces about 33 per cent, and therefore ranks first in quantity of this product, with Illinois second and Missouri third. According to the latest complete statistics (for 1905) the average value of glass sand per ton in Pennsylvania was $1.31, in Illinois 63 cents, and in Missouri 60 cents. This notable difference in prices between Pennsylvania and western sand is accounted for in part by the fact that Pennsylvania sand is somewhat more expensive to produce, being made from harder rock. A sharper, even-grained, and consequently a slightly more desirable glass sand is the result. Pennsylvania, West Virginia, and Maryland sands, all sold at a high price, are consumed for the most part within those States, and the importation of western sand would be expensive. Therefore prices are largely controlled by the cost of western sands plus freight charges. In the Mississippi Valley glass sand is produced principally from the Fox River district in north-central Illinois, near Ottawa, and from Missouri just west of St. Louis. These sands, besides supplying a large local demand, are shipped to all points within a radius of 500 miles, and frequently to a greater distance. Silica for other purposes, such as steel castings, linings of acid converters, fire brick, etc., is regularly shipped to Pacific coast points—Portland, Tacoma, and San Francisco.

The preparation of glass sand has become a highly specialized business, and in the middle Mississippi Valley 15 or more thoroughly equipped plants are at present employed. The large investments in sand properties and mills have developed very active competition between these establishments, and this competition has resulted in great care in the preparation of glass sand and in a high-grade product. Besides glass sand almost an equal quantity of other sand is produced at these plants for various purposes, such as molding, furnace lining, stone sawing, grinding plate glass, and glazing pottery. Most of this sand requires less care in selection and preparation, yet it brings almost as high a price as glass sand and therefore yields more profit.

The method of treatment of glass sand depends on the character of the deposit and on its position. Some beds of sandstone are so friable and pure that only blasting down and slight crushing are necessary before the sand is dried and screened. Many plants, however, wash their sand in course of preparation, particularly those in Illinois, where hydraulicking is employed to obtain sand from the quarries. Washing doubtless removes, even from high-grade sand, considerable silica in such a fine state as to be detrimental, as well as an appreciable quantity of undesirable impurity, mainly clay, as is indicated by the following analysis of slime from washings of sand at Ottawa:

Analysis of slime from washings of Ottawa, Ill., sand.

Silica (SiO_2)	87.21
Alumina (Al_2O_3)	7.50
Ferric oxide (Fe_2O_3)	.52
Calcium oxide (CaO)	None.
Magnesium oxide (MgO)	None.
Sodium oxide (Na_2O)	.20
Potassium oxide (K_2O)	
	95.43

Remainder mainly H_2O.

Partial analyses of sands from Mississippi

[Analyst, George Steiger, United

No.	Location of outcrop or quarry.	Owner.
	KANSAS.	
1	Sec. 20, T. 29 S., R. 14 E., Wilson County	Mrs. Hall, Fredonia, Kans
2	Secs. 20 and 21, T. 29 S., R. 14 E., Wilson County	C. D. Roberts, Fredonia, Kans
3	1½ miles southeast of Fredonia	F. Butts, Fredonia, Kans
4	5 miles southwest of Fredonia	Orval Jeffers, Fredonia, Kans
5	Sec. 36, T. 34 S., R. 13 E., Montgomery County	A. B. Cochran, Caney, Kans
6	Sec. 13, T. 34 S., R. 13 E., Havana, Montgomery County	
7	S. ½ SE. ¼ sec. 19, T. 34 S., R. 13 E., Niotaze, Chautauqua County.	George Tame, Niotaze, Kans
8	do	do
	ARKANSAS.	
9	Sec. 4, T. 17 N., R. 18 W., Everton, Boone County	
	WISCONSIN.	
10	Sec. 22, T. 4 N., R. 4 W., Flora, Grant County	
11	2½ miles southeast of Boscobel, Grant County	
	MISSOURI.	
12	Jackson, Cape Girardeau County	Jackson Lime and Quarry Co

Physical properties of sands of

No.	Locality.[a]	Color.	Angularity.
1	Fredonia, Kans	Grayish white	80 per cent
2	do	do	do
3	do	Light grayish brown	90 per cent
4	do	Yellowish brown	do
5	Caney, Kans	Light yellowish brown	Mostly sharp
6	Havana, Kans	Pinkish brown	do
7	Niotaze, Kans	White	do
8	do	Light yellowish brown	do
9	Everton, Ark	Grayish white	About 30 per cent
10	Flora, Wis	do	None
11	Boscobel, Wis	Pale green and white	Very little
12	Jackson, Mo	Faint pinkish white	do

[a] See preceding table for township, section, etc.

basin of possible value for glass making.

States Geological Survey.]

Constituent.					
Silica (SiO_2).	Magnesia (MgO).	Lime (CaO).	Oxide of iron (Fe_2O_3).	Alumina (Al_2O_3).	Total.
Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
97.59	....	....	0.33	....	97.92
98.00	....	....	.37	....	98.37
97.50	....	0.10	.43	1.62	99.65
97.94	....	....	.63	....	98.57
97.08	....	....	.72	....	97.80
97.80	....	....	.84	....	98.64
96.45	....	....	.37	2.76	99.58
96.90	....	....	.67	2.03	99.60
99.55	....	....	.09	.13	99.77
99.17	....	....	.22	.25	99.64
99.47	....	....	.07	....	99.54
99.52	....	....	.07	.16	99.75

possible value for glass making.

Sieve tests. (Percentages are approximate.)				
Larger than 20 mesh.	Passes 20 mesh.	Passes 40 mesh.	Passes 60 mesh.	Passes 100 mesh.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Small lumps	100	99	60	15
.....do	100	100	65	20
.....do	100	85	35	10
.....do	100	80	60	15
....	100	100	95	35
Few small lumps	100	100	80	20
Few lumps	100	100	100	90
.....do	100	100	90	50
A few grains	99+	97	50	10
.....do	99+	80	40	15
1+per cent	98+	35	6	1—
Fine lumps	100	99	80	10

Two methods of drying sand are in common use—the rapid method, effected by means of rotary cylindrical dryers, which operate on a principle similar to that applied in cement mills, and the slower method of allowing the sand to settle through coils of steam pipes. In the rotary driers the cylinder is slightly inclined to the horizontal; damp sand is fed in at the higher end and, aided by gravity, moves gradually toward the lower end of the cylinder. Heated and incandescent gases are forced into the cylinder, the interior of which may be fitted with an angle iron that lifts and drops the sand alternately, thus exposing it more completely to the action of heat. There is some objection to this method on the ground of overheating the sand and the consequent danger of its setting fire to the bins. If the heat is properly regulated, or if bins are of fireproof material, the danger is minimized, and since drying is completed in from five to ten minutes great economy of time is effected—an essential feature where a large output is desired. Fuller discussion of methods of obtaining and preparing sand will be found in the descriptions of individual plants under the head "Details of sand properties," below.

In the accompanying tables are given the chemical composition and physical properties of twelve sands from Arkansas, Missouri, Kansas, and Wisconsin. These sands have attracted attention, either by their purity and general fitness or by their proximity to manufacturing centers. Direct comparison with sands of proved value can be made by reference to corresponding tables in the paper "Requirements of sand and limestone for glass making," pages 452-458 of this bulletin.

DETAILS OF SAND PROPERTIES.

ILLINOIS.

The glass-sand industry in Illinois is mainly centralized in Lasalle County, along Illinois and Fox rivers near their junction. Topographic maps of Lasalle and Ottawa quadrangles, comprising this area, are issued by the Survey. The St. Peter sandstone, which is the rock utilized, has been exposed in this area as the result of erosion across a low anticlinal fold, the axis of which passes northwest and southeast about 2 miles below Utica. The lowest rock exposed along the axis of this fold is a magnesian limestone containing natural cement-rock beds. It lies just below the St. Peter sandstone and is exposed along Illinois River Valley for about 3 miles below Utica. The dips on the west limb of the anticline are very marked near the axis, but to the east they are more gentle, and in both directions the dip flattens out so as to become imperceptible. Illinois River flows in a broad, flat, rock-bottomed valley with precipitous sides, and below the rock floor of the valley the stream has cut its present channel from 20 to 30 feet in depth. As a consequence of the steep westward dip, which occurs about 1½ miles east of Lasalle, the extent of the St. Peter sandstone on the west limb of the anticline is limited to a few hundred yards. Northward beyond the river valley the sandstone forms the country rock over several townships. Eastward from Utica to Ottawa the broad Illinois Valley is cut in the flat-lying sandstone, as is the narrower valley of Fox River, to a point above Wedron. Limestones of Carboniferous and occasionally of Trenton age overlie the sandstone along the valley bluffs. Transportation facilities are extremely favorable, since two railroads traverse the valley at Ottawa, and this advantage, together with the inexhaustible quantity of very pure sand easily obtained, has brought the production of silica into prominence among the activities of the Illinois Valley.

Ottawa.—The Ottawa Silica Company's property lies about 1½ miles west of town, near the Illinois and Michigan Canal. This company operates two mills, about one-half mile apart, each mill deriving sand from an open pit sunk below the level of the valley bottom. The St. Peter sandstone lies horizontal and is everywhere near the surface throughout this portion of the valley. At these quarries a few inches to 3 feet of soil and glacial débris have been scraped away, laying bare the old waterworn and potholed surface of the sandstone. At the sides of the valley the formation rises 30 to 50 feet above the valley floor, and drilling is reported to have shown the deposit to extend 280 feet below it, so that its total thickness is probably in excess of 300 feet. At the quarries of the Ottawa Silica Company only 60 feet of sand are worked at present on account of heavy ground water encountered at that depth. The sand is mostly massive, and is frequently cross-bedded. It is pure white and free from clay where freshly exposed in these two quarries, but the water that flows from the lower portion of the pits leaves a strong iron stain. Being very friable, the sandstone breaks down almost completely in blasting, and the loose sand is washed down by a stream from a small nozzle, through a screen, into a pump. This pump forces the water and sand through a 6-inch pipe along the quarry bottom to an elevator, which carries the wet sand up into the mill. Here the sand is washed twice, dried, and screened and is ready for shipment. The prepared sand is perfectly white and consists of well-rounded waterworn grains averaging coarser than sands from the other States mentioned in this article. Sand of different degrees of fineness is screened to order. The greater part of the product goes for glass making, although some is sold for furnace lining and for stone sawing. One thousand tons per day is the average output of these two mills.

On the south bank of Illinois River about 1 mile southeast of Ottawa is the plant of the United States Silica Company. The sand is quarried by the hydraulic process from sandstone outcropping at the surface near the top of the formation. In the pit first opened four or five clay pockets or holes, similar to buried wells, filled with clay were found. The new quarry has been sunk to 100 feet in one place, in order to get a good location for a water hole. Water, some of which is strongly mineralized, flows in below a depth of 75 feet, requiring the pumping of about 600 gallons per minute. This water is utilized in hydraulicking the sand. The depth of the sand beyond 110 feet has not been determined. The sand is cross-bedded and contains a few yellowish layers, in which the grains appear slightly coarser than the average. This yellowish sand, when friable, is mined with the rest, as the color nearly all washes out. Some layers are so hard that blasting does not break them up, but crushing has not yet been resorted to, as the supply of sand that can be hydraulicked is still very great. The sand is shot down and washed, by a stream of water under high pressure, into the sump of a Nye pump. Before entering the sump the sand passes through a three-eighth-inch screen. It is raised by this pump to an air compressor, at present about 15 feet above the Nye pump. The air compressor has two tanks, which receive material alternately. The sand is raised to the mill by this compressor pump and run into bins or washers. From these washers the water which was raised with the sand is drained off into the river, then clean water is added, and the material is pumped into a second set of bins—the drain bins—24 in all. Here the sand stands about twelve hours, until the water is entirely drained off. From the drain bins the sand is shoveled out on driers. There are twelve driers, each consisting of five tiers of twenty 16-foot steam pipes. The bottom driers are closer together than the upper ones. The sand requires about fifteen hours for drying. It falls gradually through the driers onto a belt, which carries it to an elevator. From the elevator it goes through dry screens, and from the screens into storage bins. From the storage bins the sand is lowered into cars by elevating it to a delivery pipe. The best sand sold here is used for fine cut-glass ware and flint glass and bottles, the great bulk of it going to points in Indiana. Some, however, is shipped to Kansas and to Pennsylvania.

Utica.—Below Ottawa, along the Chicago, Rock Island and Pacific Railway, are a number of small sand banks producing mainly crude sand from the upper part of the St. Peter formation, but as Utica is approached the sandstone rises higher in the bluff, bringing the fine quality of sand into convenient position for quarrying. Two quarries—that of the Utica Fire Sand Company and that of E. J. Reynolds & Co.—are situated respectively 1½ miles and one-half mile east of town. These firms produce mainly a good grade of sand, which is loaded directly on cars at the quarry without crushing or screening, but they also make glass sand, employing a hydraulic jet and pump to move the material down from the bluff to the mills.

Wedron.—The Wedron White Sand Company at this place, on Fox River, 7 miles above Ottawa, is a large producer of glass sand. An analysis of sand from Wedron is given on page 456.

MISSOURI

The belt of St. Peter ("Pacific") sandstone between Klondike, on Missouri River, about 40 miles above its mouth, and Crystal City, on the Mississippi, 40 miles below St. Louis, contains the principal glass-sand plants of the State. This district is partially covered by the Survey topographic maps of the St. Louis, O'Fallon, and De Soto quadrangles. The rocks dip slightly to the northeast, but so slightly that locally they may be regarded as being horizontal. The outcrop of the sandstone in this region is from one-half mile to 5 miles wide. On the southwest the sandstone is bounded by older Ordovician dolomite and chert, while to the east it passes beneath later Ordovician dolomite, which is in turn overlain by Devonian and Mississippian limestone and shale. Mississippian and later strata constitute the country rock at St. Louis and beyond the river in Illinois, where they pass beneath the main areas of Pennsylvanian coal-bearing rocks.

Klondike.—Glass sand is produced at Klondike, on the north side of Missouri River about 40 miles above its mouth. The base of the St. Peter sandstone here is 80 or more feet above Missouri River, which flows close to the base of the bluff, just beyond the tracks of the Missouri, Kansas and Texas Railway. The sandstone is about 80 feet thick. It lies on an irregular surface of cherty magnesian limestone or dolomite, the uncomformity between the two formations being well displayed in the east pit of the quarry, where small domes of cherty rock extend up into the sandstone and coarse sandstone fills the hollows in the limestone floor. Overlying the St. Peter is a bed of soft greenish sand and clay shale, succeeded by alternating thin beds of sandy limestone, oolitic siliceous bands, clay shale, and earthy limestone, with more massive magnesian limestone beds above, the whole cover aggregating about 30 feet at the summit. This overlying formation has been termed the "First Magnesian" limestone. At present the removal of this overburden is a dead loss, since the rock is not considered of value for any purpose.

In texture the sandstone displays the well-known St. Peter characteristics of well-rounded, medium-sized grains (see table, p. 456) and is so friable as to be easily crushed. The upper 25 to 30 feet are slightly colored pink or brown in places. Lower down it becomes pure white or faint yellow. No marked cross-bedding is noticeable here, but in places there are distinct but not persistent horizontal bedding planes. Impurities are rare. Occasionally a small speck or "button" of iron oxide is encountered, cementing the adjacent sand grains into a very hard lump, but these harder masses are removed in screening. The workings of the Tavern Rock Sand Company at Klondike extend about one-fourth mile along the face of the bluff. The sand is "shot" down and gathered by means of tram cars drawn by mules to central points in the several pits, where the cars are picked up by cable and drawn to the mill. The sand is dumped directly into crushers, from which it passes to the driers. It is elevated to the screens and then falls into bins, from which it is drawn off into railroad cars for shipment. There are twin mills built on the terrace capping the steep slope between the railroad track below and the base of the sandstone. Each mill is equipped with Gates gyratory crushers, rotary-drum driers, elevators, screens, bins, and chutes. The power house is on the river bank across the track from the mill. The position of the sand bed, high in the bluff, is of advantage in many ways. The quarries are easily drained and can be worked to the full thickness of the sandstone. While difficulties were encountered in the erection of the mill on the steep face of the bluff, its position in relation to the sandstone is of advantage, for gravity is made to play a large part in the process of handling the sand from the quarry to the railroad cars. The topography of the tract being worked by this company favors long continuance of the industry. When stripping of the beds overlying the sandstone has been carried as far as practicable on the river front, quarrying may be begun on the north side of the narrow divide which lies between the river and the small ravine parallel to it, about one-fourth mile to the north. After considerable quarrying has been done on the north side the thickest limestone cover in the middle of the ridge may be economically stripped back into the north quarry, making available the whole block of sandstone constituting the ridge back of Klondike and extending nearly one-half mile east.

As the dip of the formation is to the northeast, the overburden presents an ever-increasing thickness in this direction, so that the eastward limit of profitable quarrying will be determined largely by this factor. As the sandstone in the upper 25 to 30 feet is slightly colored, it is usually kept separate from the whiter material below, which is prepared for glass making. The poorer grade of sand, after being crushed, dried, and screened, is sold mainly to steel foundries. An analysis of sand prepared for glass making from this quarry is given on page 456. The daily output from this plant at the time of visit was about 16 cars of 30 tons each.

Becker.—At Becker, a station on the Chicago, Rock Island and Pacific Railway, on the south side of Missouri River, about 3 miles below Klondike, are sand quarries, now inactive, but formerly worked by the Tavern Rock Sand Company.

Grays Summit.—Nearly a mile northeast of the Missouri Pacific depot at Grays Summit, and 6 miles south-southeast of Klondike, is the plant of the White Sand Company of Missouri. Lying nearly in strike with the beds at Klondike, the St. Peter sandstone is here at a high elevation on the divide between the Missouri River drainage and that of the Meramec. The quarries of this company are located on the southeastern slope of the divide and are connected with the Missouri Pacific Railway by a spur. Seventy-five to 80 feet of the formation have been exposed by stripping and quarrying. The base is not exposed, but the top is overlain by the "First Magnesian" limestone. A total thickness of 167 feet was reported at this place, based on the measured thickness of the exposed portion plus a thickness noted in a drill hole. While the actual thickness could not be measured at the time of visit, it seems rather doubtful that the thickness of the formation should be doubled within 6 miles. However, it is obviously thicker at Grays Summit than at Klondike. The character of the sand shows no marked variation from that of the district in general. The color is uniformly white, except for faintly tinted bands, the rock from which is easily segregated and run separately through the mill, so that a product of uniform grade is insured. Some small lumps of iron oxide cementing the sand into concretions occur, but these are easily removed by screening. The sand is crushed, screened, and dried at this plant. The principle of operation is essentially the same as that employed at Klondike, but there are differences worth noting. After being "shot" down the sand is brought by tram cars to a 30-inch belt conveyer, which carries it into the mill on a level with the base of the quarry and empties it into a crusher. The crusher consists of thirty-two 20-pound hammers revolving 1,000 times per minute. A wet screen intervenes between the crusher and the revolving driers, which are heated directly by blast from coke as a fuel. After drying, the sand is once more screened before being stored. The sand from this plant is shipped mainly to glass factories, but it is sold for all other purposes for which sand is in demand. An analysis of a sample of crude sand from this plant is given on page 456.

Pacific.—For more than thirty years the shipping of sand has been one of the leading industries of Pacific, a town on both the Frisco and the Missouri Pacific railroads, about 35 miles west of St. Louis, and to the conspicuous occurrence of the St. Peter sandstone at this place is due the former name, "Pacific" sandstone. From beyond the western boundary of the town eastward for about one-half mile the sandstone is well situated for quarrying in the bluff along the northern edge of the Meramec River flood plain. It ranges from about 80 feet above the flood plain on the west to about 50 feet above the river at the easternmost quarry. Three firms are now producing sand at Pacific.

The Pacific White Sand Company has quarries, not now in operation, just north of the town, and its main active quarry is about 1½ miles east of the town. This quarry, on the bank of Meramec River, discloses massive beds of sandstone separated by distinct bedding planes. Along one such plane near the top of the quarry occurs a seam of yellowish fine sandy shale one-fourth to one-half inch thick, and this shale appears also in the Frisco Railroad cut north of the quarry. Shale so rarely occurs in this formation that its presence here is worthy of note. It must be removed in the preparation of high-grade sand. In color the sand is mostly pure white, but striking variations are displayed, including shades of pink, light yellow to dark brown, and along the bedding planes near the thin shale the sand is light green. The dark-brown layers are not utilized, but the fainter-colored beds are sometimes worked in with the white sand, as the color of the resulting mixture is scarcely perceptible. There is considerable variation in the hardness of the sandstone. Toward the top of the quarry the sand is loosest, as it has little or no cover. Through the middle of the quarry face, along bedding planes, run certain hard crusts, where the sand has been unusually cemented. This cementation occurs in the whitest sand, which otherwise would be most desirable to work. Segregations of quartzite, termed "niggerheads," also occur. One bed of light-brown sand, coarser grained than the average, sparkles in the sunlight, as it has undergone recrystallization. This sand is said to be highly desirable for rock sawing, on account of its sharpness and coarseness. The sand is crushed, dried, and screened here. Cable and belt conveyors move the material, and drying is accomplished by steam coils, through which the sand gradually settles.

The quarries of the Missouri Silica Company are north of the railroad tracks, about three-fourths of a mile east of the union station at Pacific. A large quantity of sand has been removed from the bluff here, and the quarry now presents a face 75 feet high by 400 feet long, capped by green sandy shale and overlying limestone. Near the top the sandstone is of a greenish color and is cross-bedded. At this quarry the sandstone is very soft and friable, breaking down under the influence of a heavy rain. This condition might render possible the hydraulicking of the deposit in a manner similar to that employed at Ottawa, Ill., particularly since a large pit at the bottom of the quarry is now filled with water, and under present conditions is a hindrance to the work. The best grade of sand is obtained from the lower part of the quarry, and is used for the finer grades of glassware and plate glass; the second grade, used for window glass and fine bottles, comes from the middle beds, while the upper material is suitable for colored bottles and for jars. The extent to which this deposit has been worked brings it near the limit of profitable stripping, unless new methods of working are substituted for those common to this locality. Some sand has been obtained by excavating caves into the bluff, but owing to the looseness of the sand this method can not be depended on here unless the sand is excavated completely up to the limestone roof.

The first quarry east of the union station, north of the track, at Pacific is operated by the Pacific Glass Sand Company. A face of some 60 feet of sand is being blasted down here and crushed, washed, dried, and screened at the mill. The sandstone extends below the quarry and may reach a total thickness of 100 feet. The variations in color mentioned above are noticeable here, the colored sand running in strips and pockets. The greater part of the prepared sand from this plant goes to the works of the St. Louis Plate Glass Company, at Valley Park, Mo. The sand is subjected to two washings, which remove a small amount of "sediment," apparently a very fine clay, and also tend to reduce the color. Even after the second washing the sediment forms a thin film on successive layers of sand in the bins. The resulting color of the prepared sand is a very light yellow, imperceptible except in large masses. Plate glass made from it shows the usual pale-green tint on broken edges.

Crystal City.—Forty miles south of St. Louis, on the Frisco Railroad, at Crystal City, the plant of the Pittsburg Plate Glass Company is supplied with silica from its sand mines at that point. The St. Peter sandstone lies relatively low here, and only the upper 40 feet can be obtained by present methods. The openings are on the east side of a small ravine that enters Plattin Creek from the southeast. The sandstone rises about 30 feet above the floor of this ravine. It is overlain by thin sandy shale, with medium beds of limestone above. In working the sand the overlying rock was first stripped back as far as practicable, or until a thickness of about 15 feet of the limestone was reached. Tunneling into the sandstone was then begun, and now five or six openings enter the bluff into connecting chambers, which have largely been mined out for about 100 feet, with the exception of the pillars. Other tunnels extend in one-fourth mile farther, and considerable sand has been removed all the way back. The floor of the openings is about 5 feet below the bottom of the ravine, but it has been impossible to mine much below this level on account of ground water. About 25 feet, vertically, of sand are removed, leaving 6 to 10 feet as roof. The sand has not been removed entirely to the top, on account of the impurity of the upper beds, but it seems that the overlying limestone might make a good roof after some of the lower shaly layers are pulled down. This method of mining is reported to be more expensive than open-pit workings, where stripping is necessary for only a few feet.

The sand appears in general rather uniform in color, but contains a few pale-yellowish streaks and is a trifle coarser than that from the quarries farther north. Several very white streaks near the top are somewhat harder than the rest, but as the ground level is approached the rock becomes more and more friable. The product for melting is crushed washed, and dried. An appreciable yellow sediment is removed by washing. Crushed but not washed sand is used in the factory for grinding and beveling plate glass. In this process the sand grains are made finer and finer, and the various grades are used successively, being finally replaced by emery powder and rouge in polishing. The quantity of sand in sight that may be won by the present process should be sufficient to supply the factory, with its proposed enlargements, for several years, since on the opposite side of the ravine little has been removed except from the tunnel through which the railroad spur reaches the mine. No sand is at present being shipped from here, however, presumably because of the cost of production. The friable condition of the sand below water level suggests that much of this material might be obtained by pumping it up into the mill.

Silica.—At this place also, 32 miles south of St. Louis, on the St. Louis, Iron Mountain and Southern Railway, is a large sand quarry in the St.Peter sandstone, where beds lower than those at Crystal City are reported to be worked.

UNDEVELOPED RESOURCES.

The St. Peter sandstone, the formation furnishing all the material now being exploited in the area here considered, has a very wide extent. It outcrops in the Mississippi Valley in the States of Minnesota, Wisconsin, Iowa, Illinois, and Missouri, and also around the flanks of the Ozark uplift in Missouri, Arkansas, and Indian Territory. Wherever it has been recognized it usually presents the same characteristics, viz, massive beds of very friable sandstone, having a total thickness ranging from 25 to possibly 300 feet, composed almost entirely of well-rounded, translucent quartz grains of slight variation in size. These features, so persistent throughout its extent, render it of value as a glass sand. Consequently, wherever this rock occurs it may contain the substance at least of a glass sand. Locally the sandstone has been observed to be badly iron stained, also indurated to quartzite, both of which conditions render it of little value for glass making in comparison with the abundant unchanged material. In northern Arkansas the St. Peter formation has been found to contain a lens of dolomite, but even under this circumstance either or both the overlying and the underlying phases of sandstone may be of workable thickness. Aside from the St. Peter, there are other formations in this region containing beds of sand that, under certain conditions, may prove of value as glass material. Chief among these are Ordovician sandstones, older than the St. Peter, the Devonian and Carboniferous sandstones present in northwestern Arkansas and southwestern Missouri, the Buxton formation in the Independence and Fredonia quadrangles in southeastern Kansas, and the "Potsdam" or "Jordan" sandstone in the Wisconsin and Mississippi valleys in Wisconsin and adjoining portions of Iowa.

MISSOURI.

Southeast of Crystal City there is a good development of St. Peter sandstone, in Ste. Genevieve County, and at Jackson, Cape Girardeau County, the sand has been quarried. Samples from Jackson submitted to the office of the Survey are rather fine grained and friable and contain a small proportion of sharp or subangular grains. Some of the material is iron stained, and these portions are rather firmly cemented. (See item No. 12 in tables on pp. 462–463 for properties.) Chemically this sand is well qualified for glass making, and while the sample submitted comes near the limit of fineness, screening would doubtless render it highly satisfactory.

In southwestern Missouri, near Butterfield, Barry County, on the main line of the Frisco Railroad, is a deposit of sandstone, reported to be more than 36 feet deep, outcropping at the surface or lying below a few feet of soil. Three or four cars of sand have been shipped from this place.

ARKANSAS.

In the north-central and northwestern part of Arkansas, particularly along the valley of White River from Batesville nearly to Fayetteville, exposures of the St. Peter sandstone and Sylamore (Devonian) sandstone are common. Those deposits that face the river between Batesville and Cotter on the White River Branch of the Missouri Pacific Railway are in many places admirably situated for economical quarrying and transportation, and so far as a cursory examination would indicate they are of an excellent grade of glass sand. Survey publications relating to this region are as follows: Batesville, Mountain Home, Mountain View, Yellville, Eureka Springs, and Fayetteville topographic maps; Zinc and lead deposits of northern Arkansas (Prof. Paper No. 24), 1904, and Fayetteville folio (No. 119 of the Geologic Atlas of the United States), 1905. The sandstone mapped as "Key" in the Yellville quadrangle[a] is frequently of suitable quality. Near Everton, on the east side of the valley of Clear Creek, is a bed 25 feet or more thick of good white saccharoidal sandstone, so situated that it will not require much stripping and also convenient to the railroad. Analyses of this sandstone appear on pages 462–463 (No. 9), and show it to be of desirable quality. The Sylamore sandstone mapped in the Fayetteville quadrangle,[b] along White River, is within 5 miles of the railroad at Rogers and adjacent to a railroad at Sulphur Springs.

KANSAS.

The topographic maps of the Iola, Fredonia, Independence, and Sedan quadrangles include the area here considered. The areal geology of the Independence quadrangle was mapped in 1904 by F. C. Schrader, who makes the following statement:[c]

> In a number of localities along the western side of the Independence quadrangle, in the Buxton formation, sandstone occurring in bodies of from one-eighth to one-half mile in extent is of such purity fineness, and evenness of grain as to give promise of usefulness in the manufacture of glass. The best quality occurs in heavy beds in which the rock has been least affected or stained by the leaching of descending surface waters. Exposures occur 4 miles northwest of Caney and 2 miles north of Caney. At the latter locality the long hill is capped by sandstone having a thickness of at least 10 feet. Other exposures occur farther north. Perhaps the best is in the southern part of Fall River Township, in the SE. ¼ sec. 22, about 4 miles southwest of Fredonia. Here the rock is exposed over an area of 10 or 15 acres, and as nearly as can be judged from some local prospecting that has been done and from the topography, it is about 12 feet in thickness.

Samples of this rock were taken in October, 1905, from each of the above localities and were analyzed in the laboratory of the Survey, with the results, Nos. 1–8, page 462. Other exposures of the formation in the vicinity of Fredonia were also sampled.

At a point 2 miles north of Caney is a quarry on land of Mr. A. B. Cochran, leased by Mr. H. H. Lane, exposing the following section:

Section of Buxton formation 2 miles north of Caney, Kans.

	Ft.	In.
5. Weathered brown sandstone, with a few feet of rocky slope above.		
4. Massive, rather firm, slightly micaceous, light-brown sandstone, separated from No. 3 by a joint plane	5	
3. Massive, slightly friable, light-brown sandstone, with fine angular grains	5	
2. Yellowish shaly sandstone, micaceous, very fine grained	1	2
1. Massive soft sandstone, becoming harder on exposure. Angular quartz, with some chert grains and bands of iron rust	3	6

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[a] Adams, G. I., Zinc and lead deposits of northern Arkansas: Prof. Paper U. S. Geol. Survey No. 24, 1904, Pls. IV and V.

[b] Geologic Atlas U. S., folio 119, U. S. Geol. Survey, 1905.

[c] Economic geology of Independence quadrangle: Bull. U. S. Geol. Survey (in preparation).

A drill is said to have shown sandstone to a depth of 8 feet below the base of the exposure. This would indicate a total thickness of over 20 feet. In natural outcrops the rock is usually stained dark brown, and at this quarry a comparatively fresh exposure showed considerable discoloration, indicating that the material is deeply oxidized. Analysis No. 5 (p. 462) shows this sand to be fairly high in silica, but to contain too much iron to make anything but the commonest jar and bottle glass, and the same may be said of sand from a point on the ridge west of Havana, near the county line (No. 6, p. 462). These sands are also slightly finer than is desirable, but this may be offset by the fact that the grains are mostly sharp. Two samples from near Niotaze (Nos. 7 and 8, p. 462) proved to be altogether too fine grained and rather low in silica. The high content of alumina is due to the micaceous character of the sandstone, a feature common to the sandstones of the region. It is probable, however, that sand at present under heavier cover would prove of slightly better composition throughout this locality. This could be economically determined by shallow drilling along the sandstone ridges in the vicinity of Caney, Havana, and Niotaze, and in view of the importance of developing low-grade glass sand it might be worth while to undertake it. One drill hole in each locality, if put down in solid rock, would determine the quality of the sand much more satisfactorily than openings along the face of a bluff.

Southwest of Fredonia, along the escarpment on the south side of Fall River, the sandstone is locally almost white, and such samples (Nos. 1 and 2, p. 462) on analysis proved to carry the least iron. This rock is not so friable as the St. Peter sandstone, but it can be mechanically crushed and its evenness and comparative sharpness of grain should render it satisfactory as a low-grade glass material. The chief considerations in regard to the practicability of opening up the deposit concern the outlay for equipment and trackage, since the best material lies about 4 miles from a railroad. The large investments in glass factories in southeastern Kansas indicate faith in a long life for the industry. With permanency assured to the business, even if the cost of production here were 100 per cent greater than in districts farther east, sand might be sold at a profit and still save money to the buyer. Other outcrops, where some prospecting has been done, were found to show about 20 feet of sandstone filled with more or less ferruginous spots. The best samples that could be obtained here have been examined with results given under No. 4 (p. 462). From a bed of sandstone apparently near the base of the Buxton formation, 1½ miles southeast of Fredonia, a sample was taken, and its properties are given under No. 3 (p. 462). Only about 6 feet of a cross-bedded sandstone show here above the level of a small creek. The rock is a light-gray micaceous, porous, soft sandstone, with grains somewhat angular and a trifle coarser than is usual in sandstones of this vicinity. The rock has a sprinkling of specks of iron rust running through it. The total thickness could not be ascertained.

WISCONSIN.

In southwestern Wisconsin along Mississippi River and its tributaries, from a few miles above Dubuque, Iowa, nearly to Wisconsin River, the St. Peter sandstone is a persistent formation lying low in the valleys in the southwestern part of the area and rising to the tops of the hills toward the northeast. Where low in the section the sandstone is heavily covered by limestone and dolomite and in places is badly iron-stained, but in general it is protected from waters descending from the overlying formations by a bed of clay shale. The sandstone is usually so soft as to be worked with a pick and shovel, and it is quarried extensively for local uses, although it is by no means as sharp a sand as might be desired for building purposes. It would probably make a good glass sand, but in localities along Mississippi River near the Chicago, Burlington and Quincy Railroad, or near the Chicago, Milwaukee and St. Paul Railway on the Iowa side, where, situated close to transportation facilities, it is doubtful if it could be exploited except by mining. The distribution of the St. Peter sandstone has been mapped during the survey of the Lancaster and Mineral Point quadrangles, and the maps are expected soon to be available in the Lancaster-Mineral Point folio. Additional topographic maps that comprise outlying edges of this district are those of the Elkader, Waukon, and Richland Center quadrangles. Tests made of St. Peter sand from a point near Grant River south of Flora, Wis., indicate that its quality is all that could be desired as a glass material. (See No. 10, pp. 462–463.)

In the valley of Wisconsin River the "Potsdam" formation contains several valuable beds of clean quartz sand, rather coarse, well rounded, and loosely cemented. Exposures, probably of the "Jordan" sandstone horizon, occur in the bluffs near Boscobel, Wis., in close proximity to the Chicago, Milwaukee and St. Paul Railway. The properties of sand from this locality are given under No. 11 (pp. 462–463). The chemical composition is excellent and the sand is of very desirable size.

GENERAL ASPECTS OF GLASS-SAND INDUSTRY.

The consumption of glass sand has been rapidly increasing for many years, and it is probable that it will continue to do so indefinitely. Vast resources of the material are in sight. The uses for glass are now so varied and extensive that it may well be classed with iron and cement in its importance under present conditions. Glass sand in situ possesses relatively little intrinsic value. The market value is due to the labor cost of extraction and preparation.

The factors on which a deposit of sand depends for its possible value for glass making are (1) chemical composition, (2) physical character, (3) amount available, (4) location with respect to fuel supplies, (5) conditions of quarrying or mining, (6) location with respect to transportation routes, and (7) location with respect to markets. The first two have been treated rather fully in the foregoing pages.

A deposit so thin as 20 feet should have an areal extent of at least 20 acres of good sand in sight to warrant the erection of a mill and trackage. Most deposits are thicker than 20 feet, but it would be safer to have a much higher ratio between areal extent and thickness than the minimum given. Where ledges of sand require stripping of overlying limestone, the limestone may in certain cases be of such purity that it also could be used for glass making; if this is not the case other uses should be sought for it as a by-product. In regard to fuel, every plant turning out glass sand in quantity sufficient to net a profit must be equipped with power for moving the sand and drying it, and in most cases with equipment for cleaning it as well. The margin of profit is at present so low that the cost of preparation can not reasonably stand freight charges on coal for more than 50 miles. Natural gas would be a suitable fuel, especially in the operation of rotary driers. In respect to transportation routes, the general principle "the more available the better" is applicable. Aside from the necessity of securing fair and uniform freight rates experience has shown, especially where the dependence is on only one railroad for transportation, that shortness of cars at certain seasons may seriously handicap a plant in its shipments and lead to cancellation of many orders. In respect to markets, it must be considered that sand is for its value one of the bulkiest products, and therefore one whose cost to the consumer is greatly influenced by distance. At the same time the question of permanence of these markets must be considered.

Some of the large sand properties, together with their mills, represent an outlay of about $75,000, a sum that requires good business judgment for its investment and subsequent careful management in order to keep it paying adequate interest. Strong competition in the Middle States has forced prices down very low at present, and competition in the form of the small producer who leases a sand bank and works out by hand and team all the choice sand within convenient distance and then abandons the quarry, having figured only daily wages to himself as profit, has resulted in some embarrassment to the larger companies.

THE GLASS-SAND INDUSTRY IN EASTERN WEST VIRGINIA.

By George W. Stose.

The deposits of pure quartz sandstones occurring between Hancock, Md., and Berkeley Springs, W. Va., have been quarried for many years, but it is only within the past few years that mining operations have become active.

Geology.—The sand is derived from a white sandstone composing the Warm Spring Ridge in West Virginia, which runs south-southwest from Potomac River opposite Hancock, Md. This formation is the Oriskany sandstone and is part of a monoclinal series of beds between a massive anticline bringing up Medina sandstone in Cacapon Mountain, 1½ miles to the west, and a sharp syncline of Carboniferous rocks forming Sleepy Creek Mountain, 6 miles to the east. The rocks strike N. 10°-25° E. and dip 50° SE. On the west, beneath the sandstone, are limestones of Helderberg age and shales of Cayuga age. Above it, on the east flank of the ridge, is a belt of black shales of Marcellus and Hamilton age, followed by Chemung rocks.

Character of the sand rock.—The sandstone of this ridge is of exceptional purity. In other outcrops of this formation to the east and west, where it is brought to the surface by folding, it is commonly a siliceous limestone with chert nodules and fine conglomerate. The pure sand rock seems to be limited to a few miles in length along the strike of the Warm Spring Ridge, for northward in Maryland it changes to a yellow, impure, and coarse sand rock, suitable only for building sand. Its extent southward has not been determined. It is mined as far as Berkeley Springs, the end of the railroad spur up the Warm Spring Valley, but the same character of rocks at the surface seems to continue far beyond, and the land is held largely as sand land, its development awaiting the extension of the railroad.

This pure white quartz sand is evidently a beach or near-shore deposit, and its purity, freedom from mud and other fine detritus, the uniform size of its particles, and their subrounded character indicate long-continued sorting action at this part of the shore. The grains are of medium fineness, practically all passing a 40-mesh sieve and 25 per cent passing a 60-mesh sieve. Particles of milky cryptocrystalline silica are scattered among the grains; whether these are original chert fragments or were deposited there from solution is not known. The grains are loosely cemented by lime, the Berkeley Springs water, which issues from the upper beds of this formation, containing a small percentage of carbonate of calcium. At the surface the rock is hardened and slightly glazed, apparently by the solution and redeposition of silica between the grains. In depth, however, the rock is commonly soft, breaking into grains in blasting or by the use of the sledge hammer.

Pennsylvania Glass Sand Company.—The oldest mine, located near the north end of the ridge, is operated by the Pennsylvania Glass Sand Company. The mine is but 2 miles from Hancock. It is located on the top of the ridge, where the edges of the sandstone beds outcrop in rocky ledges 300 feet above the Baltimore and Ohio Railroad track along the river at the west foot of the ridge. This mine was established before the branch railroad up the Warm Spring Valley was built, and the only direct railroad communication was by the main line to the west. The western side of the ridge is composed of Helderberg limestone, through which a tunnel had to be constructed to reach the sandstone on the eastern side. The mine is a large open cut, 120 feet deep, about 130 feet wide, and 400 feet long. At its south end is a tunnel in which much rock has been quarried, but this method of mining has been abandoned and the whole width of the ledge is now being worked as an open cut.

About 150 feet of rock are exposed in the quarry and most of this is available for glass sand. The total thickness of the formation is probably about 170 or 180 feet. The upper part is a hard bed 20 feet thick which is not mined, but is used as the east wall of the hole. On account of the steep eastward dip it overhangs and is to some extent a source of danger, as in places it has caved in. The sandstone as quarried varies from pure white to creamy and is generally fine grained with an occasional coarse bed. Below the surface it crumbles on being quarried and the sand is handled largely by shovel. Large lumps are readily broken with a sledge hammer, and the few masses from harder beds which do not yield to this treatment are thrown aside and not utilized, as this company does not use a rock crusher. The rock is drilled by steam, the power plant being located on the old floor of the quarry on the level of the tramway tunnel. The quarry has since been carried 30 feet below this level, which necessitates a cable tram to haul the loaded cars to the grade of the tunnel. On account of the inclosed character and the depth of the quarry the heat becomes unendurable in the summer, and a canvas awning is suspended over the workmen to shield them from the sun.

From the mouth of the tunnel 200 feet above the railroad a narrow-gage railroad runs to the mill at the river, three-fourths of a mile north. The grade on this tramway is sufficiently gentle for mules to haul the empty cars over it, but recently a small locomotive was installed. At the mill the sand and rock are passed through a roller or mull and then washed and dried, the product being a pure white quartz sand, suitable for making table, window, and plate glass. The capacity was reported to be 200 tons a day. The mill was destroyed by fire early in 1905, but has since been rebuilt.

The other mines on this ridge are all located on the eastern flank along the Warm Spring Valley. The construction of the Berkeley Springs Branch of the Baltimore and Ohio Railroad from Hancock to Berkeley Springs made the eastern part of the Warm Spring Ridge accessible to the railroad and was the cause of the recent rapid development of the mining industry. Two companies began operation about the same time, the Berkeley Springs Sand Company and the West Virginia Sand Company.

Berkeley Springs Sand Company.—This company opened a mine at the northern edge of the town of Berkeley Springs. This is the southernmost opening on the ridge. The quarry, like all those on the eastern side of the ridge, is midway on the slope, about 150 feet above the valley bottom, and near the base of the sandstone exposure. It is an open cut 200 feet long by 100 feet across and 50 or 60 feet deep. It is entered by a short tunnel through the harder cap rock forming the eastern face, which is not quarried here. The rock appears to be of excellent quality and has furnished a high grade of sand. A cable tramway leads to the mill in the valley. The mine was shut down during the writer's visit in 1904, and its capacity was not determined.

West Virginia Sand Company.—The first mine operated by this company is located one-half mile north of the quarry of the Berkeley Springs Sand Company. In 1904 it opened a second quarry and mill, adjoining the first. These quarries are 200 feet above the valley. The older opening was about 100 feet square, exposing throughout white rock somewhat harder than that at the Pennsylvania Company's mine. The cap rock is hard, coarse, and somewhat impure, but is mined and, together with 10 feet of surface stripping and weathered streaks where the sand is stained yellowish, makes a second grade of sand, used for bottle glass and railroad sand. Ninety per cent of the rock produces sand of No. 1 grade, pure white, and containing over 98 per cent of SiO_2. This is used for plate and window glass and tableware. The very choicest is reported to run 99.8 per cent SiO_2 and is used for the finest cut glass.

The stone is drilled by compressed air and is brought to the mills in the valley by two double-track gravity cable tramways. The material is assorted at the quarries and the surface rock and other second-grade material is sent to the old mill for treatment. The better grade rock is taken to the new mill on elevated tracks and dumped into chutes which lead directly to two mulls, the larger fragments being first sorted out and run through a Blake crusher. In the mulls, which are circular vats in which revolve two heavy iron wheels at the ends of an axle, it is crushed wet, until it will pass through a fine screen into the washers. These consist of long inclined boxes in which large screws revolve, and the sand is churned and cleaned as it is carried upward by the screw against a flood of water down the box. The tailings are deposited in settling yards and make good building sand. The washed sand is conveyed by horizontal continuous belts to the drying room or to temporary bins on the way. The drier is a slowly revolving inclined cylinder over a fire box. The hot, dry sand is delivered at the lower end into cups of an endless chain, which carry it out of the building to elevated iron storage tanks on concrete piers, ready for loading by gravity. Every precaution against fire is taken in this modern plant, since the former mill was destroyed by fire from overheated sand deposited in wooden bins. The capacity of the two mills is 10 carloads of 30 tons a day, and the average shipment is reported to be 6 cars.

In the summer of 1905 the same company opened two new quarries and was erecting two new mills within a mile of the old quarries, and the company is said to have bought up all the property between the Berkeley Springs mine and the Pennsylvania mine, except a small area known as the Spear property, which was opened in 1905 by an independent company.

In the town of Berkeley Springs a pulverizing mill is operated by the National Milling and Mining Company, which is under the same management as the West Virginia Sand Company. Some of the highest grade of sand is pulverized at this mill for use in porcelain, china, and glazed-brick manufacture.

Silica Sand Company.—In 1904 a sand mine was opened on the west side of Cacapon Mountain, 1½ miles west of Berkeley Springs. This mountain is composed of Medina sandstone, the core of the massive anticline previously referred to. The opening is along the Berkeley Springs-Great Cacapon road, on the west crest of the ridge, and is owned by the Silica Sand Company, of Pittsburg, Pa. A hole 20 feet wide and 150 feet long had been quarried into the face of the hill, exposing low westward dipping beds of hard quartzitic sandstone somewhat stained with iron. The quarry is admirably located for handling the product by gravity 500 feet down the slope, on a grade of about 70° to the railroad. At the bottom of the incline a mill has been constructed with the different compartments arranged in terrace form, utilizing gravity in crushing, washing, drying, and storing the product ready for loading on the cars. So far as the writer knows, however, the plant has not been in practical operation.

The rock is so hard, even at the depth attained, that it must all be crushed and thoroughly ground, and even then it does not separate into grains, but breaks into fragments of various sizes, much being reduced to a powder. The product, therefore, is not so suitable for high-grade glass, and the greater amount of grinding necessarily adds to the cost of production. The surface appearance of the rock is also not favorable, as it has a grayish cast with numerous iron stains, but an analysis was not obtained and its exact composition is not known. The successful operation of this mine, although so admirably situated for a gravity plant, is very dubious on account of the character of the rock, and further mining on this outcrop is not to be encouraged.

Other sand quarries.—At Hancock, on the Maryland side of the river, the Warm Spring Ridge sand rock is quarried, but is coarse and impure and furnishes only a low grade of yellow sand for building purposes. This was extensively used by the Western Maryland Railroad in the concrete work along its new extension to Cumberland. A similar building-sand quarry is located opposite Great Cacapon, W. Va., 8 miles up the river, where the same Oriskany sand rock outcrops on the other side of the Cacapon Mountain anticline mentioned above. This rock appears to be of better grade than that at Hancock, but is much harder. The product was largely used in the construction of the same railroad.

MISCELLANEOUS NONMETALS.

VOLCANIC ASH NEAR DURANGO, COLO.

By Lester H. Woolsey.

Introduction.—Deposits of volcanic ash suitable for abrasive material have been reported to occur in Colorado north of La Veta Pass in Huerfano County, near Wray Station in Yuma County, and near Durango in La Plata County. In this paper the occurrence near Durango will be considered. During the field season of 1905 the writer visited the deposits in La Plata County and procured the data for the following sketch. The distribution, occurrence, and character of the known deposits were studied, but the results of the investigation were such that no careful search was made for others.

Distribution.—These deposits form three isolated beds which lie within a radius of 4 miles of Durango. One is located at the east end of the dry valley north of Animas City Mountain, on the shoulder of the southward-facing spur. Opposite the west end of the same valley, on the crest of the ridge between Dry Gulch and Junction Creek, occurs another bed. Both of these deposits have the same elevation—about 400 feet above Junction Creek at this point. The third bed lies nearly east of Durango on the east slope of Florida Mesa, 250 feet above Florida River. All these beds lie at nearly the same elevation and have a somewhat similar mode of occurrence.

Occurrence.—The broad geologic features of this region are as follows: The rocks consist mainly of the conspicuously colored Jurassic, Triassic, and Cretaceous sediments which overlie the Carboniferous beds exposed farther north. The whole series is gently upturned to the north and northwest and wraps about the south and west margin of an old Archean surface. Upon the beveled edges of these sediments the deposits of volcanic ash occur. The deposit north of Animas City Mountain lies across the edges of the main upper sandstone of the La Plata formation and the overlying thin beds (Jurassic-Triassic). The actual contact is concealed, but the bottom of the ash is very near bed rock and 20 feet may be considered a maximum interval. Above the ash no rocks occur in place, and the covering consists of rounded pebbles, possibly of glacial origin, dislodged blocks of conglomerate, and fragments of shale belonging to the Cretaceous. The form of the deposit is probably that of a horizontal lens, possibly occupying an irregularity in the bed-rock surface. The extent of the lens is no doubt small, for ash is more or less evident about 100 feet horizontally along the outcrop, and its thickness ranges from 25 to 50 feet. The weathered exposure shows thin horizontal laminations, as if the material were deposited in quiet water. The bed on the ridge southwest of Junction Creek presents a conspicuous outcrop of white ash, lying upon the dark-gray shale of the Cretaceous. It is covered chiefly by rounded gravel, probably of stream origin, mixed with shale and sandstone fragments. In size and form the bed at this point resembles that last described. The lens has been partially eroded and the exposed surface is not over 150 feet long and 15 feet wide. No stratification was apparent and the bed exhibits a homogeneous mass.

The occurrence on Florida Mesa was at the time of visit not well exposed, but over an area approximating 2 acres fragments of ash were thrown out by ground animals. It was reported to have been uncovered in several places years ago and excavated to a depth of 3 feet. The covering consists of a few feet of soil and mesa gravel, and the underlying bed rock belongs to the coal-bearing series of the Cretaceous. From the above facts concerning these ash beds it may be concluded that they occur with no regard to horizon in the sedimentary series, that they are all overlain by surficial deposits, and that they are small in extent, probably occupying basins in an old topography. This old land surface, if we may judge from the elevation of the ash deposits, was not so deeply dissected by streams as it is to-day, and the present dissection may be considered as deepest in the lower courses of the present streams. New deposits of volcanic ash, therefore, are not likely to be found along the lower courses of streams, but may be discovered on the crests of ridges or high up on the valley sides.

Character.—All three occurrences are very similar in appearance and exhibit a very fine dust-like powder of white opaque flakes which glisten in the sunlight. The powder has a gritty feel and was not seen consolidated in a hard mass. Under the microscope the powder is seen to consist chiefly of thin minute flakes with angular edges and fair uniformity in size for all the beds. Nearly all the flakes exhibit the transparent amorphous and isotropic character of glass, but some particles show interference colors, extinction, and other characteristics of quartz grains. Few of the glass flakes show air bubbles, and the material on the whole resembles powdered volcanic pumice and may be considered volcanic dust or ash. It is entirely similar to the volcanic ashes from Montana and Idaho collected by Peale of the Hayden Survey and later described by Merrill. The chemical content is no doubt largely silica, and the composition is probably close to that of similar ashes already analyzed, as follows:

Analyses of volcanic ash.

	1.	2.
SiO_2	68.92	68.91
$Al_2O_3+Fe_2O_3$	16.22	6.12
MgO	Trace.	....
CaO	1.62	3.44
Na_2O	1.56	3.09
K_2O	4.00	.36
SO_3	....	8.88
Ignition	[a] 6.00	8.75
Water	1.60	....
	99.92	99.55

[a] Organic.

1. Marsh Creek Valley, Idaho. G. P. Merrill, Am. Jour. Sci., vol. 32, 1886, p. 202; J. E. Whitfield, analyst.
2. Average sample from Nebraska. E. H. Barbour, Proc. Nebr. Acad. Sci., No. 5, 1895, p. 13; H. H. Nicholson, analyst.

Relations.—Deposits of this sort, to judge from published reports, are very common through Nebraska, reaching into South Dakota and Wyoming on the north and west and into Kansas and Oklahoma on the south. In many localities the beds are apparently very extensive and in some places very thick, but usually they are thinner than the Durango beds. The bulk of the deposits on the Great Plains, as stated by Barbour, are fine and uniform, but variations are known, and the ash may be coarse, of a dark-gray color, or mixed with sand, silt, etc. He notes the eastern limit to be Iowa, where the deposits are very fine, while in

Nebraska the beds grow coarse and heavy toward the southwest, and he suggests that the source is in that direction. Scattered deposits, besides those in Colorado, Montana, and Idaho, above mentioned, have also been found in Arizona and Nevada. The age of the deposits in the various States, according to published accounts, is not the same, for ash beds occur at several horizons and in many localities contain distinctive fossils. The beds have been found to range from the Oligocene up into the loess of the Great Plains. In the Durango deposits, however, no fossils were observed, and the indications of age are limited to the relations of occurrence. These restrict the age to post-Cretaceous and probably pre-Pleistocene. The nearest known deposit bearing fossils is in Huerfano County, 140 miles east of Durango. Vertebrate remains discovered there by R. C. Hills have been referred to the Pliocene. While this deposit closely resembles the Durango beds in character and is but a short distance away, its geologic relations are not similar, and the correlation of the two occurrences can not yet be made.

Development and uses.—The bed north of Animas City Mountain has been prospected by Mr. Charles Naegelin, the owner, by means of a shaft to a depth of 12 feet and by auger borings several feet deeper. He has made no attempt to prepare the material for market. He was formerly owner of the deposits west of Junction Creek, which he sold several years ago to the Lavaline Company, of Durango. This company has opened the bed by a surface excavation 10 feet deep and 20 feet in diameter. The ash was chuted into carts and hauled to Durango, where it was put up in packages for market as a cleaner. For some reason the company failed and ceased operations, and now the property is abandoned. The bed on Florida Mesa, owned by Mr. Spencer, was opened eight or ten years ago, but for what purpose is unknown.

Ash of this sort in other parts of the West was used by early settlers, it is said, as a plaster for building purposes, but it crumbled and was not durable. It is now locally used in many of the States named as a scouring powder and is put up, especially in Nebraska, under the names "Nebraska Silicate," "Geyserite," "Gibson Grit," "Diamond Polish," etc., and sold as a polishing powder. It has also been used to some extent in the manufacture of sand soaps at Denver and Omaha, but it is said to be not so good for this and other cleaning purposes as the imported article, because the latter is made of particles very angular and pointed, whereas the domestic material consists of flat glassy scales.

That the Durango deposits may likewise be used as an abrasive for many purposes is undoubted, but in view of the reports that in Nebraska, where it can be loaded on cars at $2.50 to $3 a ton and where freightage is low, the yearly output of the whole State does not exceed $5,000, it seems that the Durango deposits are chiefly valuable for local consumption. Of the many uses which have been suggested for this kind of ash may be mentioned semi-fused filling brick, fireproofing, and mineral wool for packing as a nonconductor of heat and sound. It might also be used in its natural state as a nonconductor of heat in refrigerating, and there seems no reason why it should not be used as one of the elements in the manufacture of puzzolan cements, and perhaps of some varieties of glassware.

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GRAPHITE IN MAINE.

By George Otis Smith.

Two occurrences of graphite in western Maine were visited by the writer in 1905. At one locality, near Madrid, Franklin County, development work had been prosecuted throughout the summer by the Maine Graphite Company, so that the relationships of the deposit were well exhibited. The other locality is in Yarmouth, Cumberland County, and although no recent work has been done here the exposures are sufficient to indicate the character of the deposit. These two occurrences are of interest from both the industrial and the scientific standpoint. The evidence presented in the following descriptions has a scientific value as indicating two modes of origin of graphite, but these genetic relationships have in turn a direct and important bearing on the question of economic value.

MADRID OCCURRENCE.

The Madrid graphite deposit is located in the town of Phillips, although only a short distance from the little village of Madrid. The nearest railroad point is Madrid station, on the Phillips and Rangeley Railroad. The schist, which together with intrusive granite constitutes the country rock in this region, outcrops here along the northern slope of a hill immediately south of the village. Beds of varying composition can be distinguished in this schist and indicate a northeast-southwest strike. The general dip is nearly vertical, although the schist is much contorted. The development work is in the form of an open cut which extends into the hill approximately parallel with the strike of the schist, the face at the southwest end measuring about 30 feet in length by 25 feet in height.

In the upper part of the face on the western side there is a triangular area of fine-grained white rock with a sandy texture. This rock contains varying amounts of quartz and, where it cuts directly across the schist, shows a selvage of muscovite and a general banding conformable with the contact with the schist. Another mass of similar rock, somewhat coarser grained, occurs in the eastern part of the same face, the two being separated at one point by not over 2 feet of schist. Near the entrance to the cut and on the east side is another mass of white rock which probably connects with the second. This third mass is plainly pegmatitic in texture and composition, containing quartz and muscovite, with subordinate amounts of feldspar. Close examination of the other masses of white rock, especially where exposed on the hill slope above the open cut, makes it evident that these are also of pegmatite. The three somewhat irregular-shaped masses may be regarded as possibly portions of one intrusive body of pegmatite, which in part cuts across the schist and in part follows the bedding planes.

The graphite occurs locally in the schist, always close to the contact with the white rock, with the exception of the sporadic occurrence of a few slickensided lenses of graphitic rock, about 18 inches in their longer diameters. At no place seen in this rock cut did the graphitic portion of the schist extend more than a few inches from the contact. At the point in the face of the cut where the two bodies of pegmatite are nearest together the schist is crumpled and crushed into blocks which appear to be largely graphite. However, all of the schist is not strongly graphitic at the pegmatite contact. Where the bedding planes can be traced with certainty, it is seen that one stratum may be graphitic and the beds on either side relatively barren, even at the point of contact with the pegmatite. This pegmatite-schist contact is well defined, and while the muscovite selvage contains a small content of graphite, the muscovite does not apparently extend into the schist.

Microscopic examination of thin sections of these rocks simply confirms the field evidence. The schist contains varying amounts of graphite, adjoining beds also differing considerably in their other constituents. A specimen collected at a distance of several feet from the pegmatite contact is a quartz-biotite schist in which graphite is present as very fine dust, which gives the gray color to the rock. A thin section cut from another rock, apparently relatively barren of graphite although close to the contact, shows a similar small content of graphite dust, the mass of the schist being composed of muscovite, quartz, tourmaline, and pyrite. The adjoining bed, which was mentioned above as graphitic, is a schist darker in color, but when the rock is studied in thin section the amount of graphite present is found to be small. The abundance of needles of brown tourmaline doubtless contributes to the dark color, and pyrite is again present, in close association with the tourmaline.

A thin section of the best grade of graphitic rock collected at the Madrid cut shows this schist to contain small grains of graphite evenly distributed throughout the rock. This is in most intimate association with muscovite, the small folia of muscovite being thoroughly interwoven with the graphite flakes and grains. In other bands fine grains of quartz form the matrix for the graphite particles. The schist is beautifully foliated and a glance at either the hand specimen or the thin section leads the observer to overestimate the amount of graphite present. This is due to the fineness of grain and the thorough dissemination of the graphite throughout the rock. Although it is evenly distributed in the rock, the foliated character of the graphite causes the surface of this graphitic schist to seem very rich in graphite. The graphite particles are in reality minute and range from 0.20 to 0.01 mm. in diameter, the average size being less than 0.04 mm.

A sample was collected of the best of the graphite schist as exposed in October on the face of the cut at Madrid. The amount of graphite in this sample was determined in the Survey laboratory by E. C. Sullivan as 8.5 per cent.

YARMOUTH OCCURRENCE.

In the town of Yarmouth the graphite locality is about one-half mile northwest of the village. The country rock in the southern part of Cumberland County is a fissile schist, fine grained, but apparently not at all carbonaceous. This schist in the town of Yarmouth is cut by large intrusions of granite, and in one of the large masses of granite graphite-bearing pegmatite occurs. This pegmatite has been prospected at several points within 200 yards and occurs in the form of a dike with an average width of 1 foot. The exposures were not sufficient to determine whether there is not a possibility of two parallel dikes being present rather than a single dike. At one point a basaltic dike is in contact with the pegmatite, and, though the contact relations are not at all plain, the pegmatite is presumably the older.

The pegmatite is for the most part of medium grain, and quartz and feldspar are the principal constituents. Small amounts of mica occur, but only sporadically, while graphite is an important constituent. A few nests of graphite about an inch in diameter occur in the pegmatite, but the most of the graphite is in the form of disseminated flakes evenly distributed throughout the rock. No definite difference between the content of graphite near the walls of the dike and that at the center could be noted, nor was any variation noticed in the amount near the contact with the basaltic rock.

Examined microscopically, this pegmatite is found to resemble other pegmatites except in the presence of the graphite. Quartz, orthoclase, and plagioclase form a mosaic similar to that typical for granite. The only other constituent present is biotite, which occurs in small amounts and is largely altered to chlorite. The graphite, as already mentioned, occurs in the larger masses and in flakes. These lustrous flakes are disseminated in the larger masses of quartz and throughout the finer-grained matrix. No graphite was noted in the larger crystals of feldspar. As seen in the thin section of the pegmatite, the graphite forms irregularly shaped masses, interlocking with the quartz grains. These flakes and smaller masses range from 1 to one-half millimeter in their longer diameters.

A chemical determination of the graphite in a representative sample of this graphitic pegmatite from Yarmouth was made by Mr. Sullivan and shows 9 per cent to be present.

ORIGIN OF THE GRAPHITE.

The field observations and microscopic study indicate clearly a difference in the character of the graphite in the two occurrences described. The Madrid graphite is exceedingly fine grained and of the variety that is often called amorphous graphite, although the minute particles are in reality crystalline, possessing all the luster of the larger flakes of the Yarmouth graphite. This lack of similarity in size of particles and the differences in form of occurrence are suggestive if not indicative of wholly different modes of origin.

The presence of graphite in the Madrid locality, at the contact between an intrusive mass of pegmatite and somewhat carbonaceous schist, at once suggests a contact origin for the graphite. The relative concentration of the graphite at the contact indicates that the processes active in the formation of that mineral were connected with the intrusion of the granitic magma rather than with the dynamic forces which have affected to some extent the rocks of the region. The source of the carbon thus crystallized into graphite was presumably in the original sediments from which the beds of schist were formed. This inference is based on the variation in content of graphite in adjoining beds even at the pegmatite contact, a variation believed to express the original difference in percentage of carbon in the successive layers of muddy sediments. The possibility is recognized, however, that certain parts of the schist may have exercised a selective influence in the concentration of the graphite, just as it is noted that these adjoining beds contain varying amounts of tourmaline, which doubtless originated from the pegmatite magma. The graphite at Madrid is believed to be the product of the conversion and concentration of carbonaceous particles of sedimentary origin through the agency of the heated vapors issuing from the intrusive rock magma now consolidated as pegmatite.

In the Yarmouth occurrence there is no evidence of any source of the carbon of the graphite other than in the molten rock itself, which intruded the granite. The graphite is as much an essential and original constituent of the pegmatite dike as is the quartz or the feldspar. The graphite crystallized possibly later than the feldspar, but plainly earlier than the quartz, and like these minerals was of magmatic origin.

ECONOMIC CONSIDERATIONS.

The practical questions concerning these deposits refer to the quality of the graphite and the quantity present. Certain deductions may be made from the observations given above and may serve to answer the question of economic worth.

The graphite at Madrid is of the type often called amorphous, a relatively low-priced material except when fairly pure and free from other minerals. As has been noted above, the size of grain in this graphite is minute and its association with muscovite and quartz very intimate. These two characters would render even partial separation of the graphite and mica especially difficult. The size of the larger grains being only 0.2 mm., and the average being less than 0.04 mm., the graphitic rock would need to be crushed so as to pass at least a 200-mesh screen before the complete separation of graphite from the mica could be effected. Such a procedure would be impracticable, and it is very doubtful if crushing to 60-mesh size would facilitate separation of the graphite from the other minerals. In short, the intermixture of graphite and mica is on so minute a scale as to prevent recovery of anything but a very impure graphite by any known method of separation.

The quantity of graphite present is also disappointing. The results of close observation of the occurrence at Madrid clearly point to the localization of the graphite at the contact of the schist with the pegmatite bodies. Exploration of the schist away from these contacts in the hope of discovery of other and larger deposits would be unwarranted. The amount of graphite exposed along these contacts would vary much from place to place, but judging from the exposures seen in October, 1905, as well as the nature of this deposit, the tonnage of even 8 per cent product would be too small to form the basis of profitable mining. Any doubt as to the truth of this statement regarding quantity is at once set aside, if the difficulties of milling the rock are considered. It is difficult to conceive of a practicable process by which this graphite percentage of 8.5 would be increased to 20. Even if a product of that grade could be secured, it would hardly be marketable in competition with higher grade graphite. The content of graphite would be too small to give the material much value even for the manufacture of paint or stove polish, while the impurities present would unfit it for other purposes.

The graphite at Yarmouth differs greatly from that already described. The size of the flakes is larger and the proportion of graphite present more constant. The smaller individual flakes vary from one-half to 1 mm. in diameter, with larger flakes often 2 mm. or more in diameter. If this rock were crushed and sized on a 60-mesh screen it seems probable that the material would be in good condition for a mechanical separation of the associated minerals. The small amounts of mica noted might make it difficult to secure a perfectly pure product. The fineness of this clean graphite would affect its value, but a coarser and more valuable product might be secured by improved methods.

The percentage of graphite in the Yarmouth pegmatite is given above as 9. The sample analyzed was collected as representative of the whole dike so far as seen in the few exposures. If this truly represents the proportion of graphite present, it indicates roughly the amount of rock that must be quarried to secure a ton of commercial product. This becomes an important factor in the question of practicability of utilizing this deposit, especially since the dike is so narrow that the amount of dead work would be proportionably large. On the other hand, the proximity to the seaboard is one feature favoring the working of the Yarmouth deposit. All these details need to be carefully considered in estimating the cost of mining and milling the graphitic product. Thus, while flake graphite is present in good amount in the Yarmouth dike, the practical value of the deposit is somewhat in doubt in view of the size of the dike in which this mineral occurs. It is probable that this dike is persistent for a considerable distance horizontally and to whatever depth it could be profitably followed, and there seems no reason to expect the content of graphite to change essentially.

Other occurrences of graphite are reported in Maine, and are believed to belong to one or the other of the types described above. Their economic utilization is desirable, yet it involves questions, similar to those suggested in this article, which deserve careful consideration. Thorough investigation will be necessary in each case to determine the actual value of the deposit.

SURVEY PUBLICATIONS ON MICA, GRAPHITE, ABRASIVE MATERIALS, ETC.

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SURVEY WORK ON WATER.

In addition to the investigations of the metallic and nonmetallic resources of the country, which are carried on by the geologic branch, the Survey, through the division of hydrology, has also made extensive studies of the occurrence, character, and economic value of underground waters, including mineral water and water used for public, industrial, and irrigation purposes.

The value of mineral waters sold for medicinal and table purposes alone is over $10,000,000 annually, which places them among the most valuable mineral products of the country, while it is probably safe to say that the value of the water used for public supplies and irrigation is more than that of all other mineral products combined.

The results of the investigations of mineral waters are published in a series of reports on "Mineral Resources," which appear each year, while those dealing with all other classes of water are issued mainly as Water-Supply and Irrigation Papers. Occasionally, however, important papers relating to waters have appeared in the Geologic Folios, Bulletins, Annual Reports, and Professional Papers. The various papers on underground waters may be classed as follows:

1. Detailed reports, consisting of descriptions of the occurrence, quantity, and quality of the underground waters of limited areas. Nearly every State is represented, but few are completely covered.
2. Preliminary reports, containing summaries of the occurrence of underground waters. All States east of Mississippi River and a number of those west of the river have been covered.
3. Reports on mineral and potable waters.
4. Reports on springs and spring deposits.
5. Papers on artesian requisites, movements of ground water, etc.
6. Report on laws relating to underground waters.
7. Reports on measurements of flow and head.
8. Lists of wells and borings.

In addition to the special reports on underground waters a large number of Survey papers on other subjects contain more or less important references.

For a complete classified list of special publications on underground waters, Water-Supply and Irrigation Paper No. 160, entitled "Underground-Water Papers, 1906," should be consulted. A full subject index of Survey publications on ground waters up to the beginning of 1905 will be found in the "Bibliographic Review and Index of Papers Relating to Underground Waters published by the United States Geological Survey, 1879-1904," issued as Water-Supply and Irrigation Paper No. 120.

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